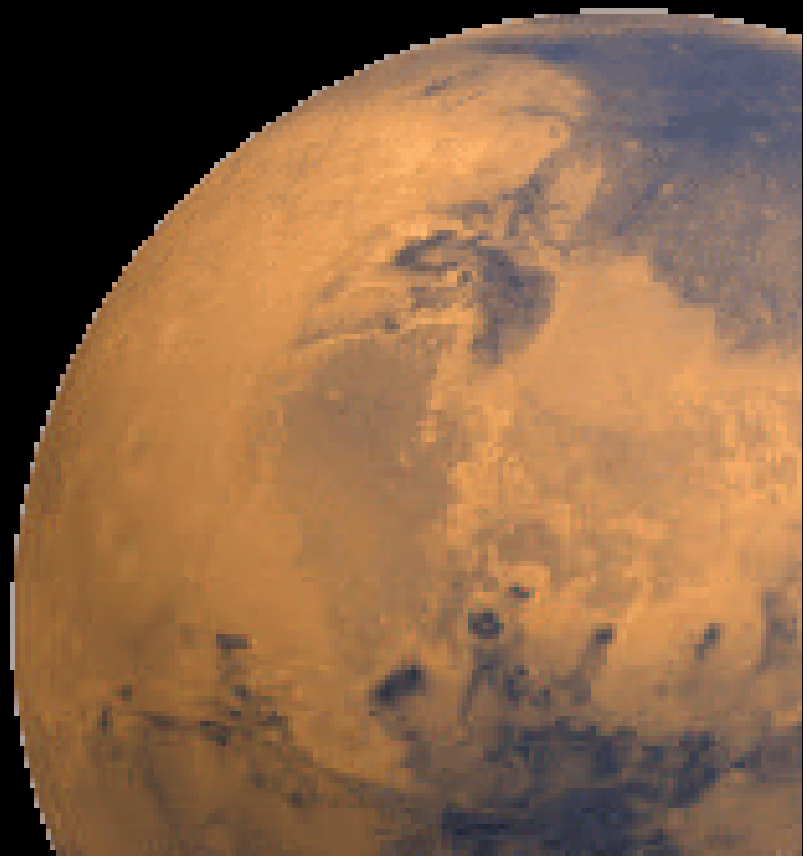
Arnauld E. Nicogossian, MD
Associate Administrator
NASA Office of Life & Microgravity Sciences & Applications

Space Medicine Revisited

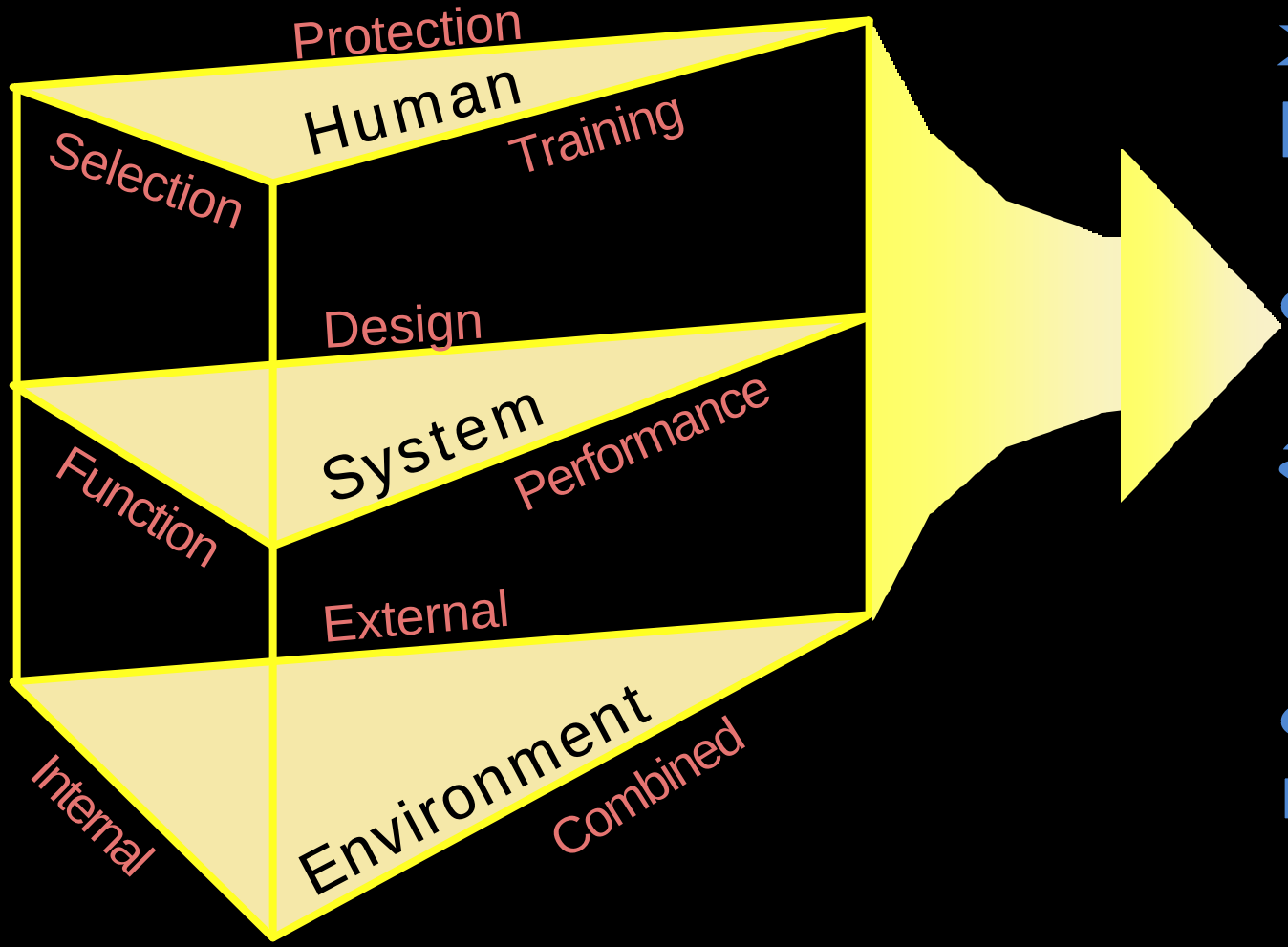


Contents

- **Planning for human space missions, a three-pronged approach**
  - Human
  - System
  - Environment
- **Confronting biomedical responses to space flight**
  - Physiological response
  - Delivering medical care
- **Advanced technologies for human support**
- **The International Space Station as a testbed**

Human Space Missions

System Human Environment



Exploration

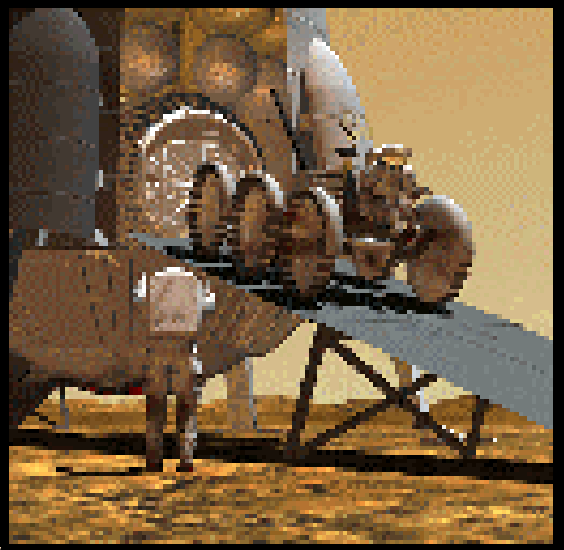
Strategic Framework

NASA's MISSION

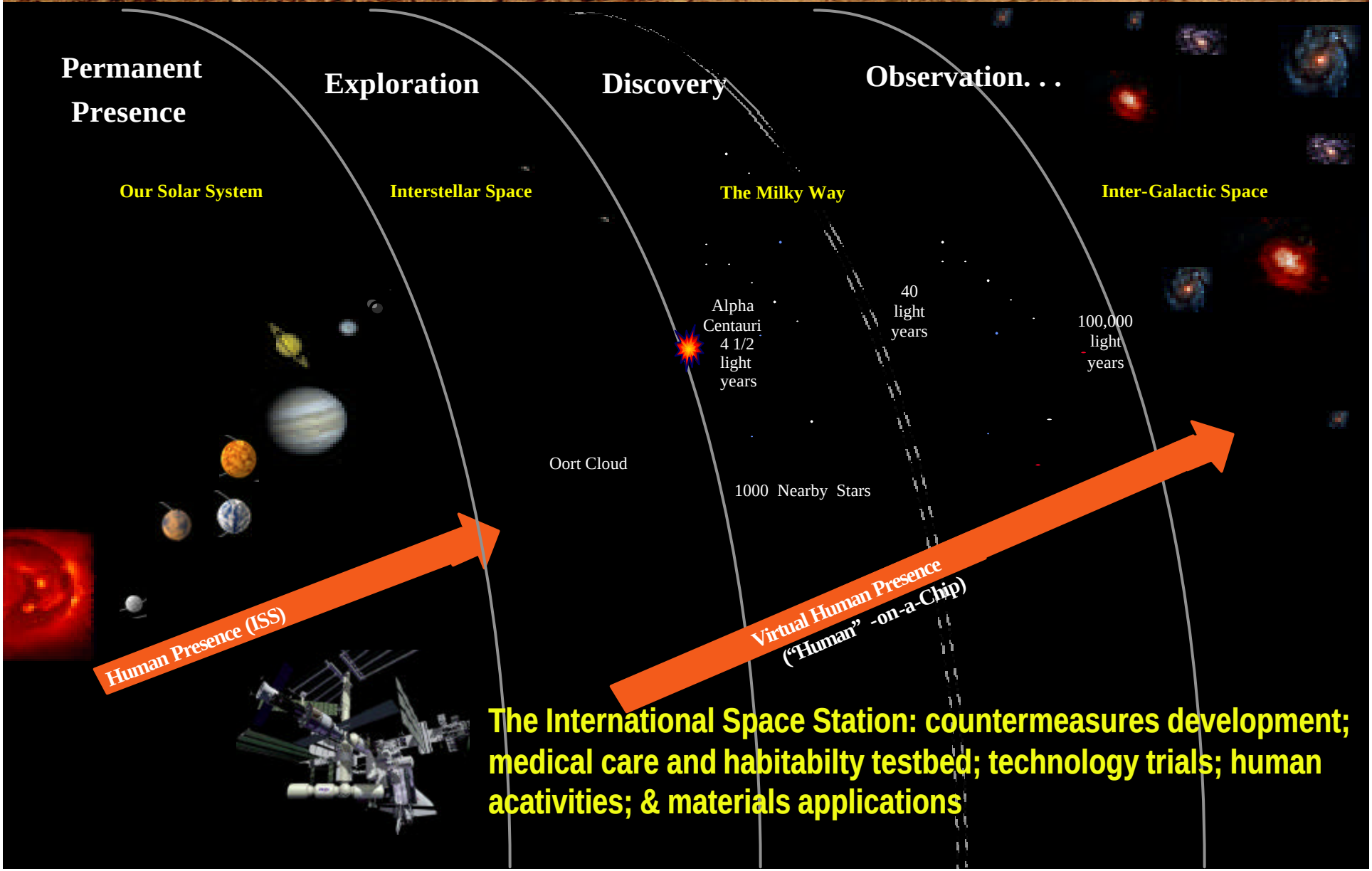
…advance…knowledge

…explore…space

…transfer…technology



Exploration and the ISS



The International Space Station: countermeasures development; medical care and habitabilty testbed; technology trials; human acativities; & materials applications

Pillars of Biology

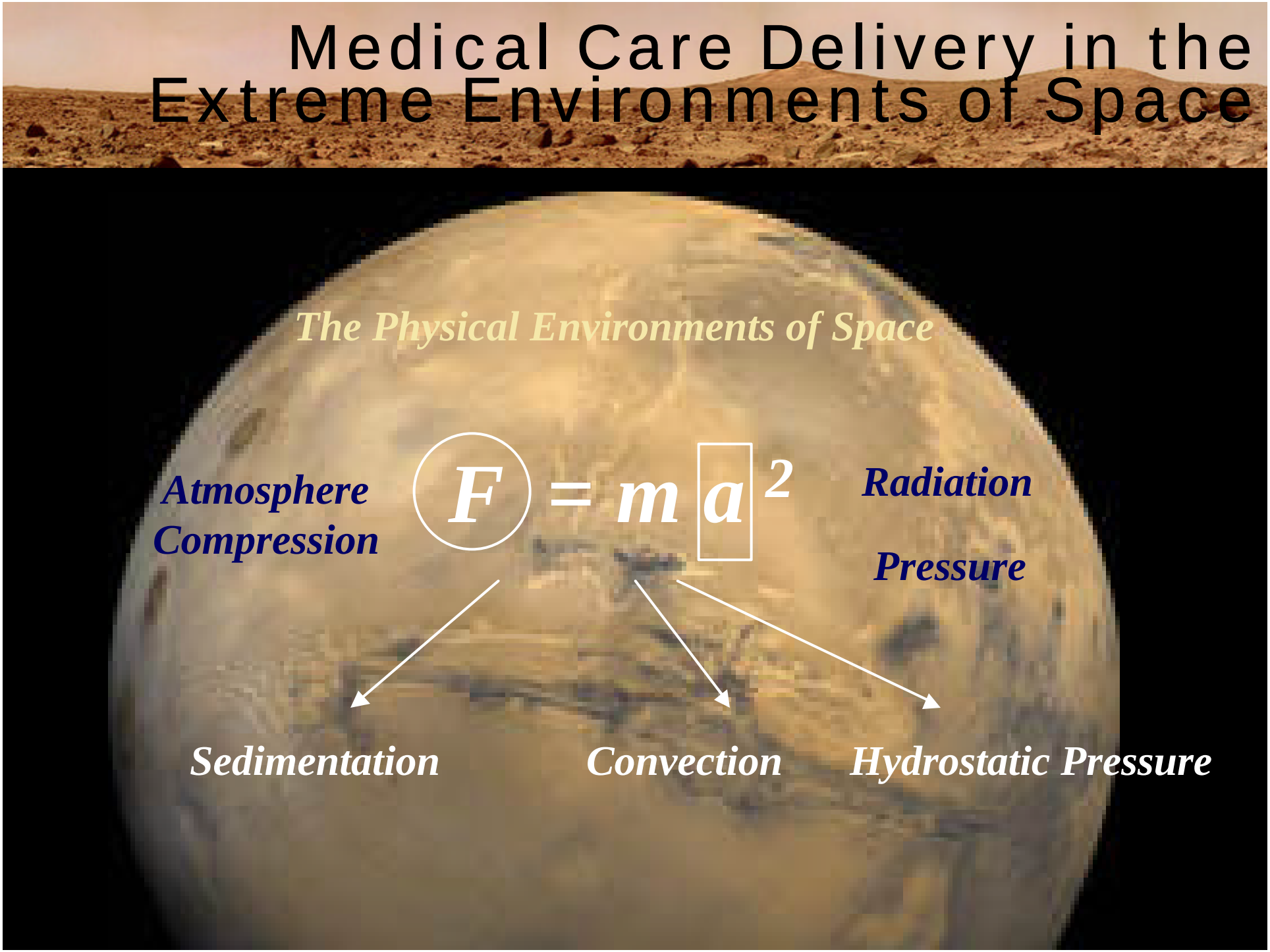
Astrobiology

…searching for life

Bioastronautics

Life into space...

Medical Care Delivery in the Extreme Environments of Space

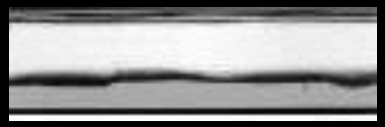
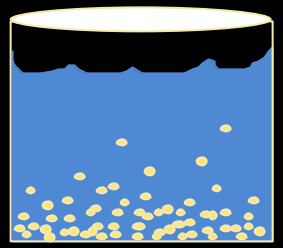
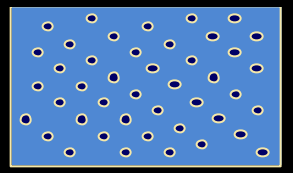


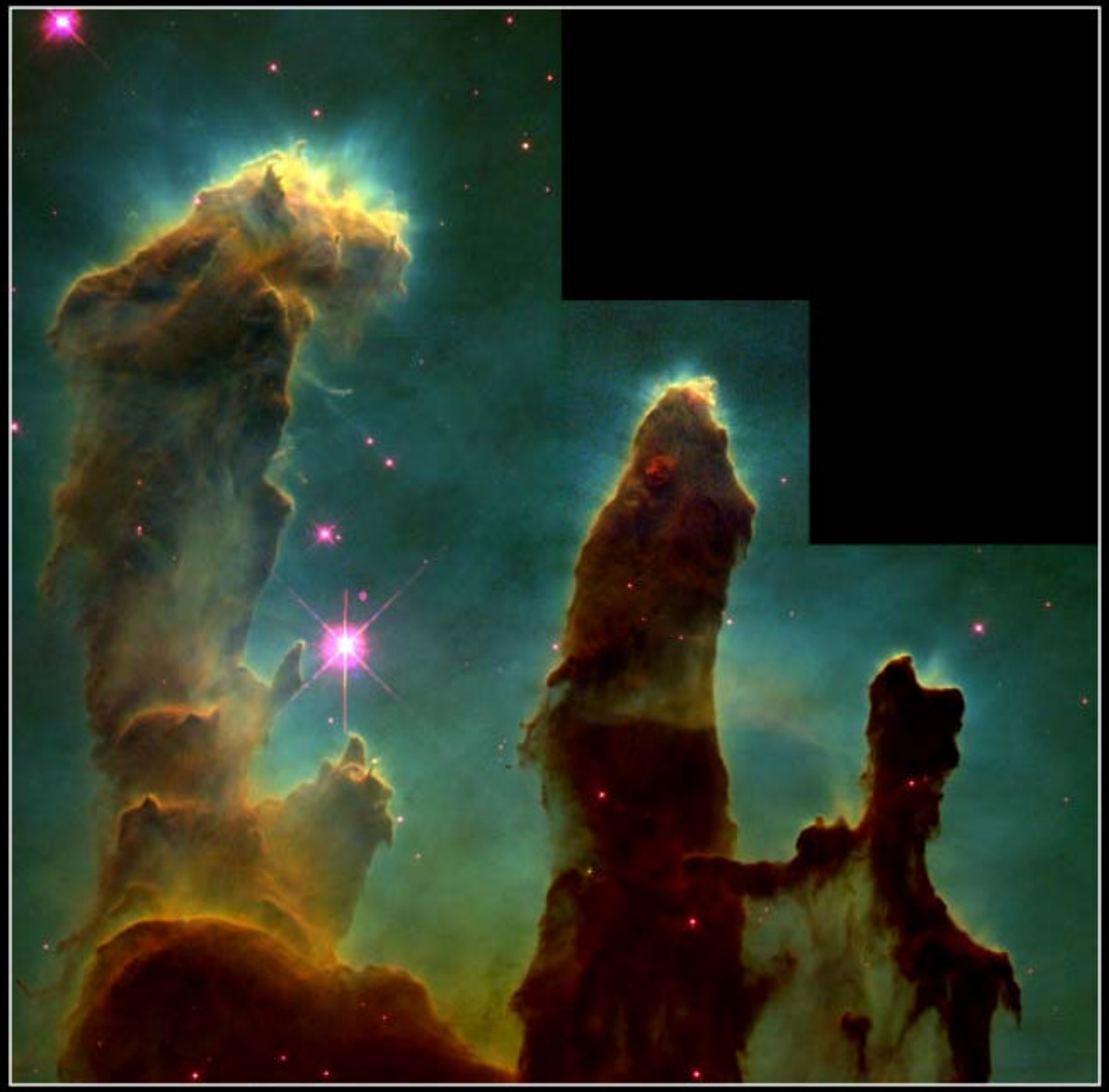
System Human

Environment

External

Microgravity

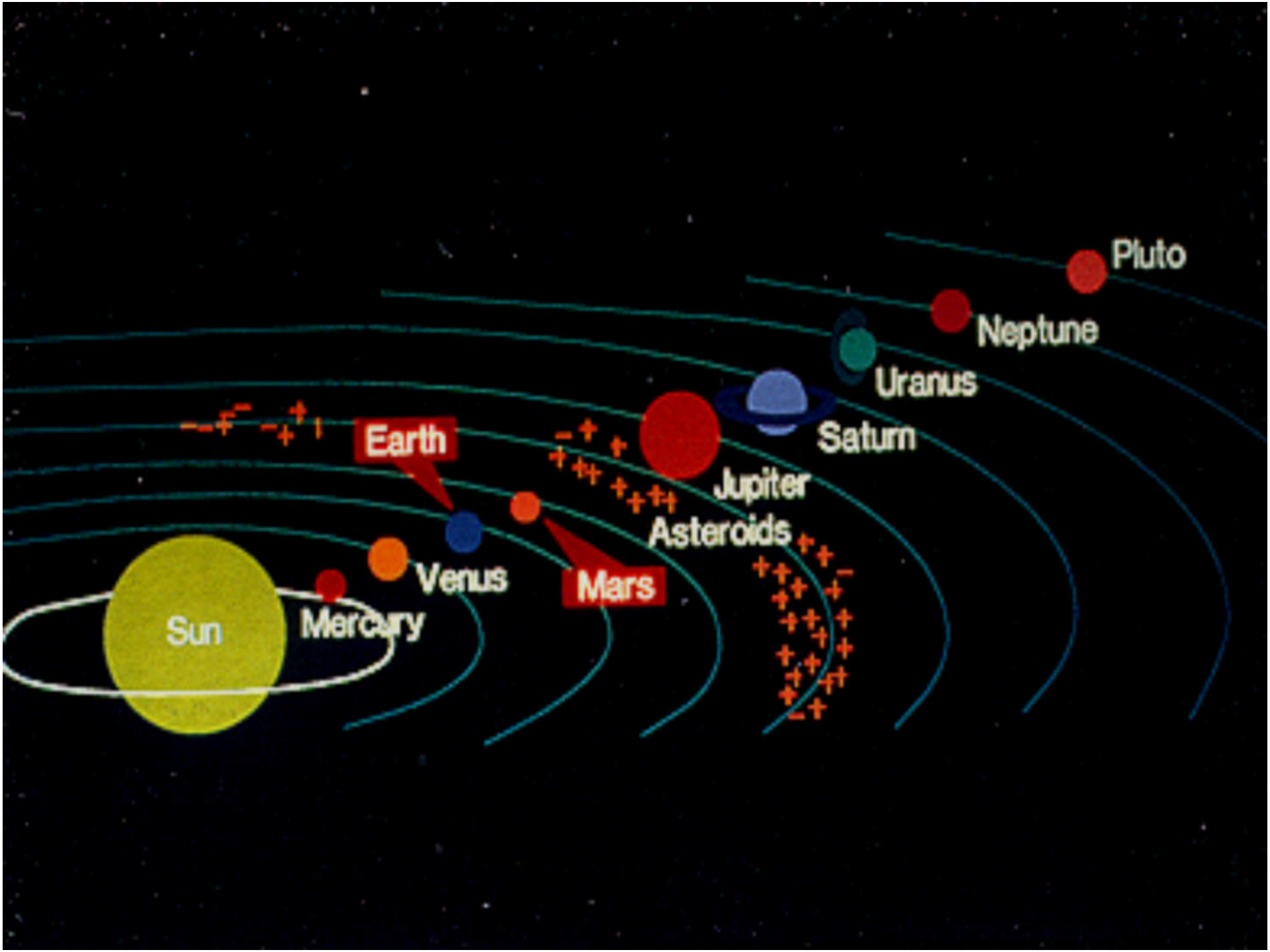
	Convection	Buoyancy	Sedimentation
Earth			
Space			

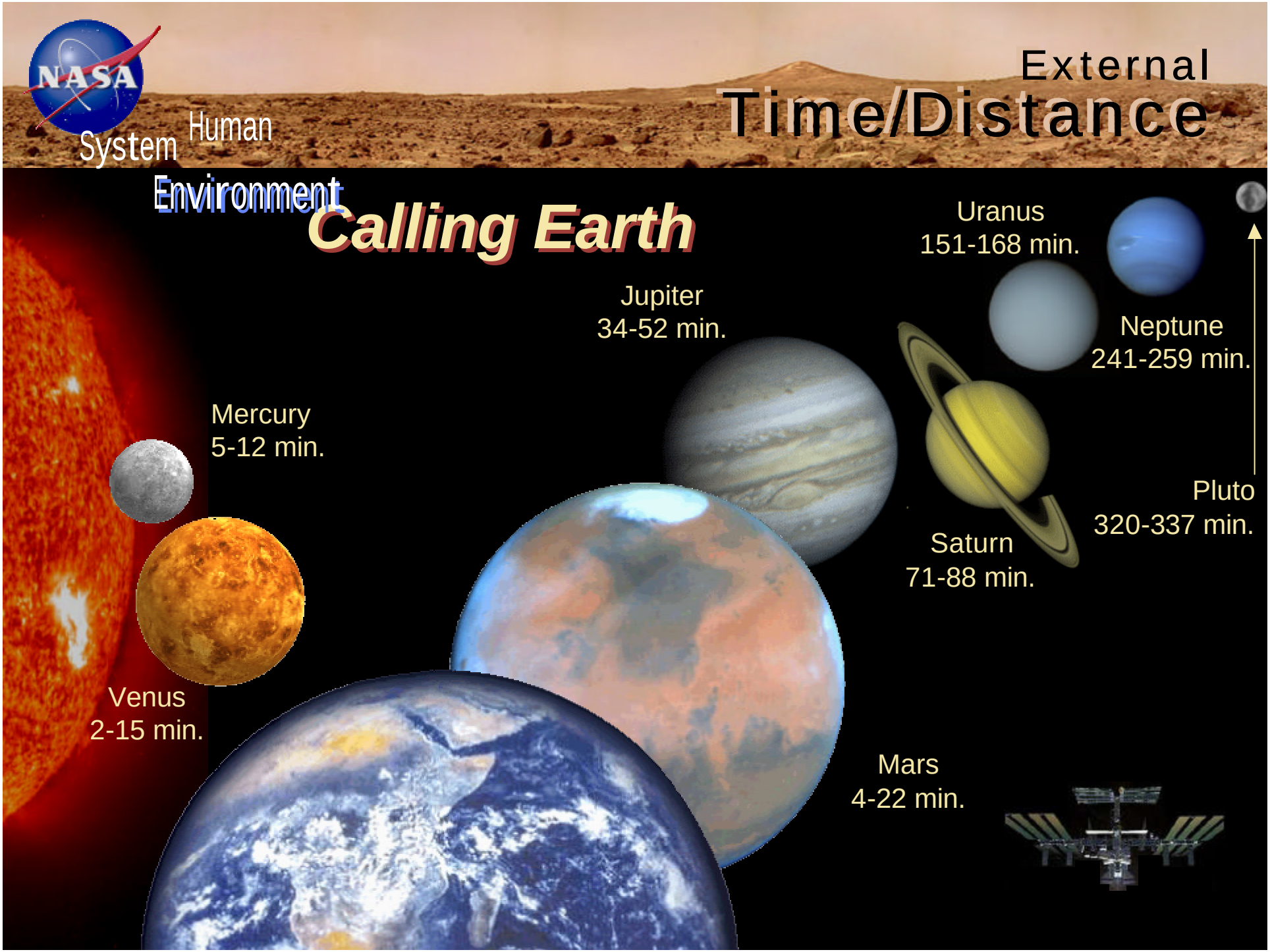


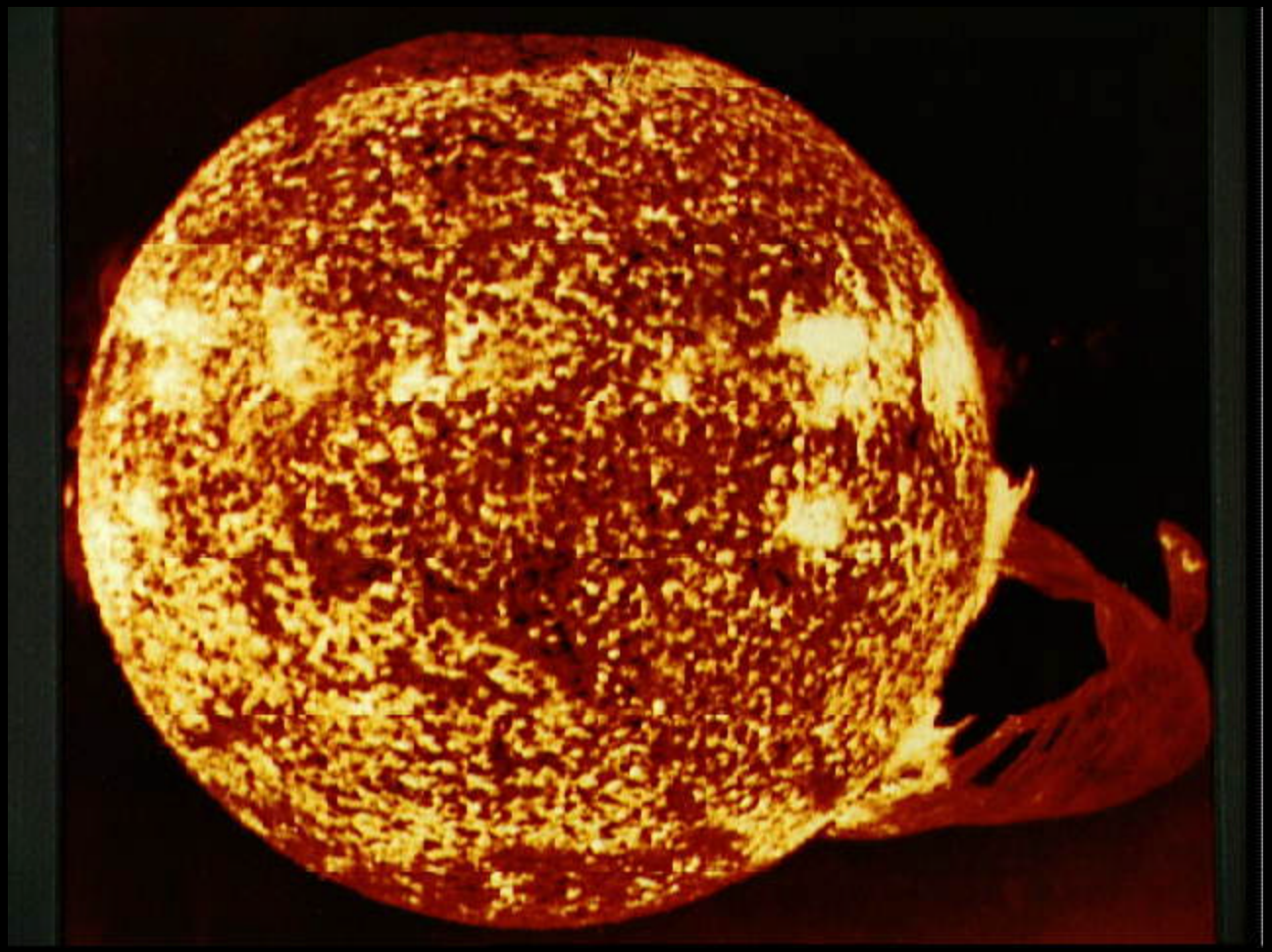
Gaseous Pillars · M16 HST · WFPC2

PRC95-44a · ST ScI OPO · November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA


YOU ARE HERE

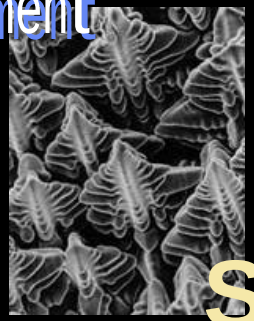

Pluto
Neptune
Uranus
Saturn
Jupiter
Asteroids
Earth
Mars
Venus
Mercury
Sun


NASA
System
Human
Environment
External
Time/Distance
Calling Earth
Uranus
151-168 min.
Neptune
241-259 min.
Jupiter
34-52 min.
Mercury
5-12 min.
Pluto
320-337 min.
Saturn
71-88 min.
Venus
2-15 min.
Mars
4-22 min.



External Radiation

System Human Environment



Secondaries

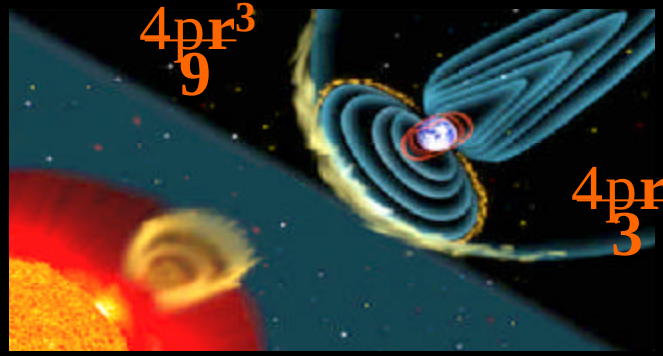
Heavy particles

Protons

Neutrons

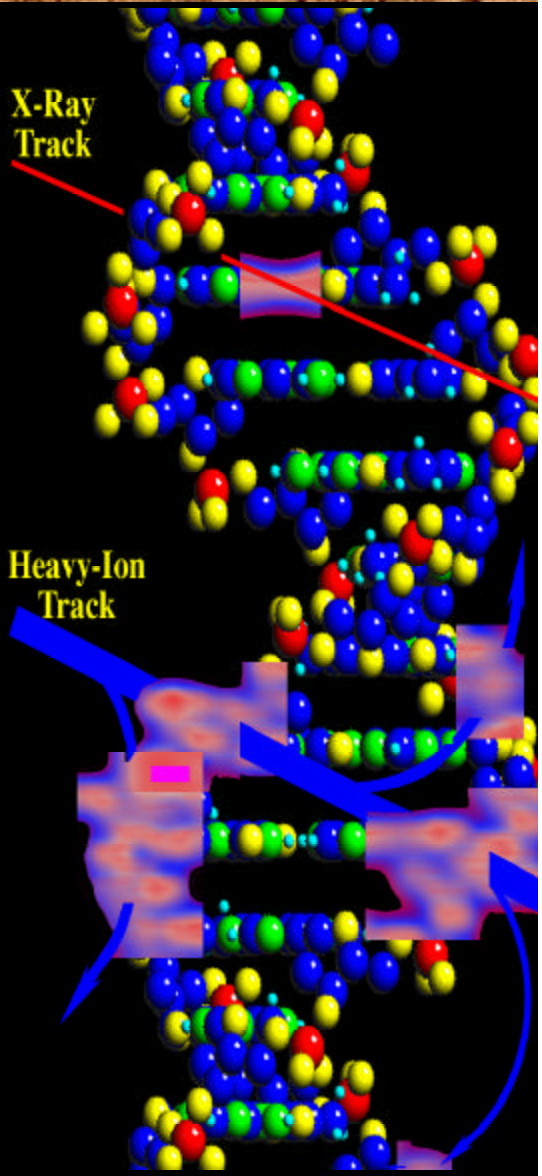
Electrons

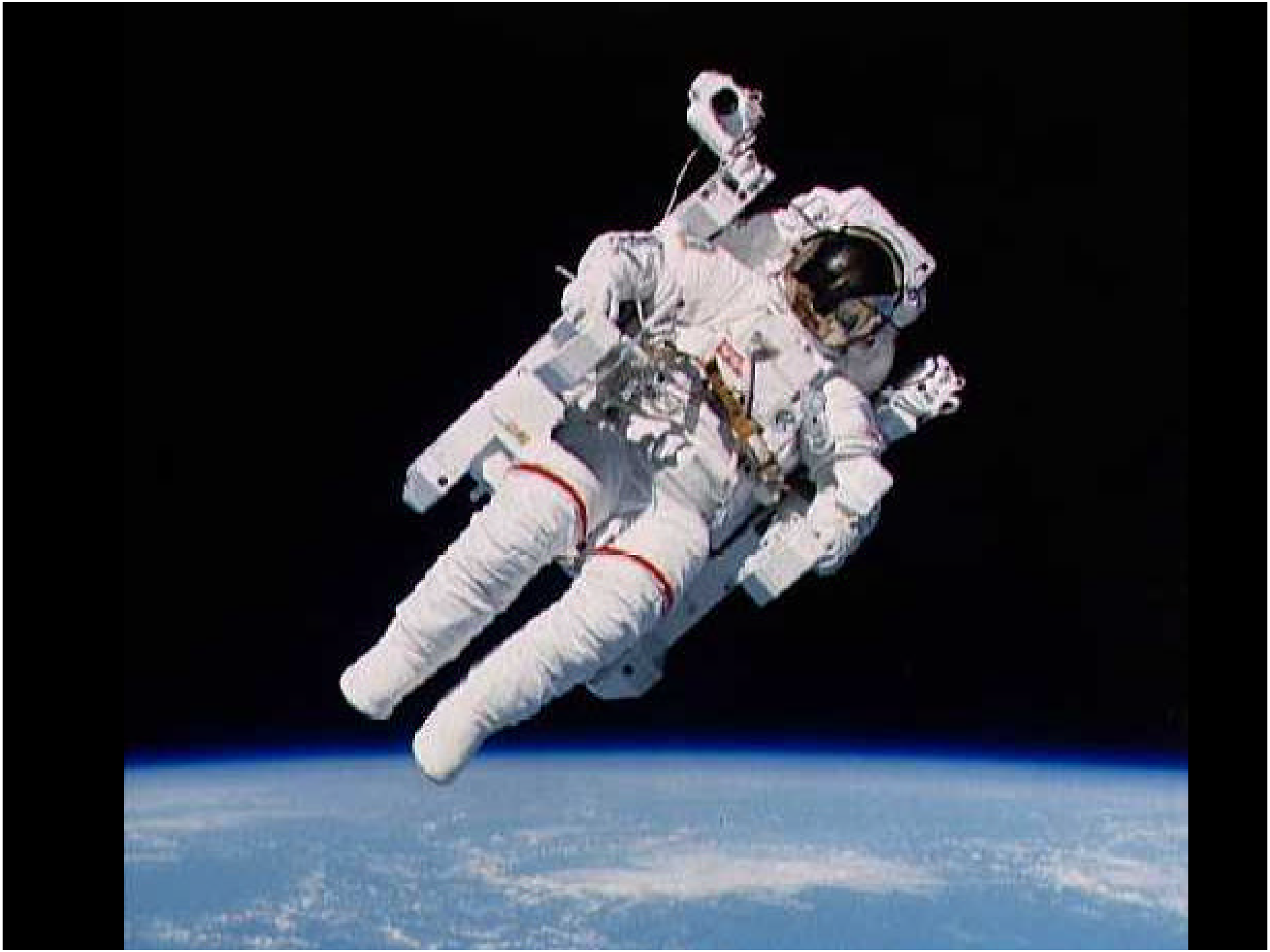
H^-

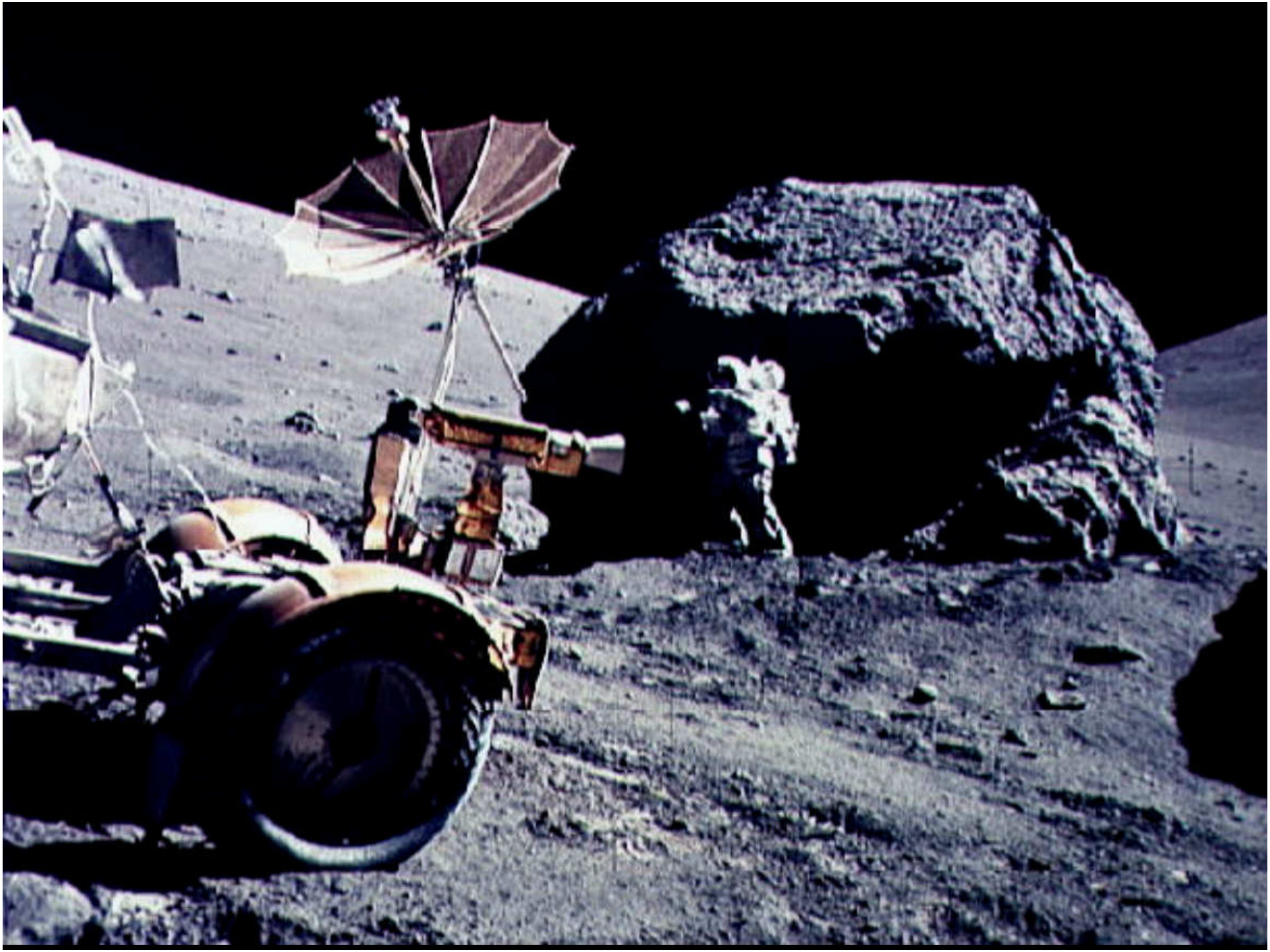


$\frac{4\pi r^3}{9}$

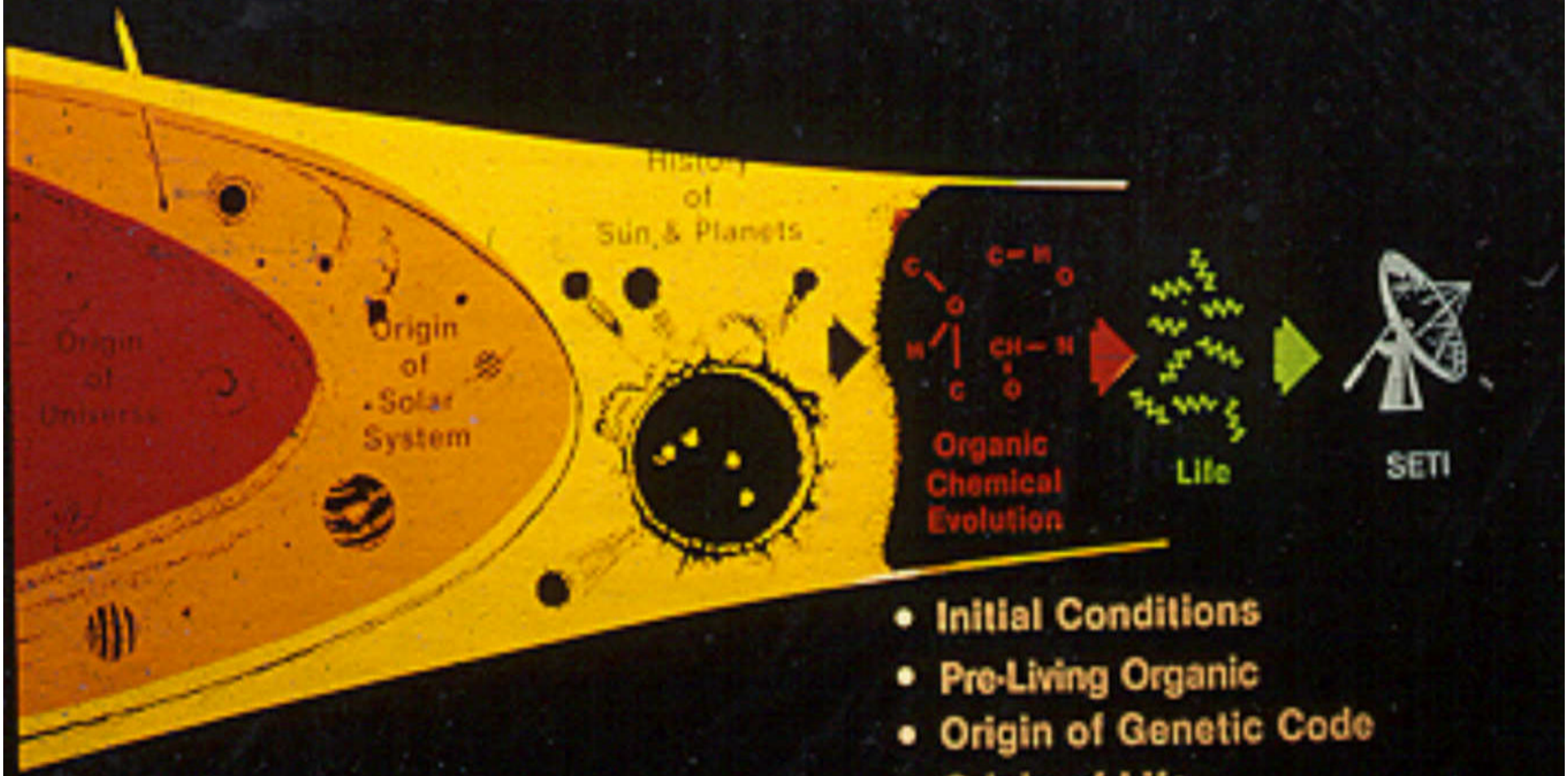
$\frac{4\pi r^3}{3}$





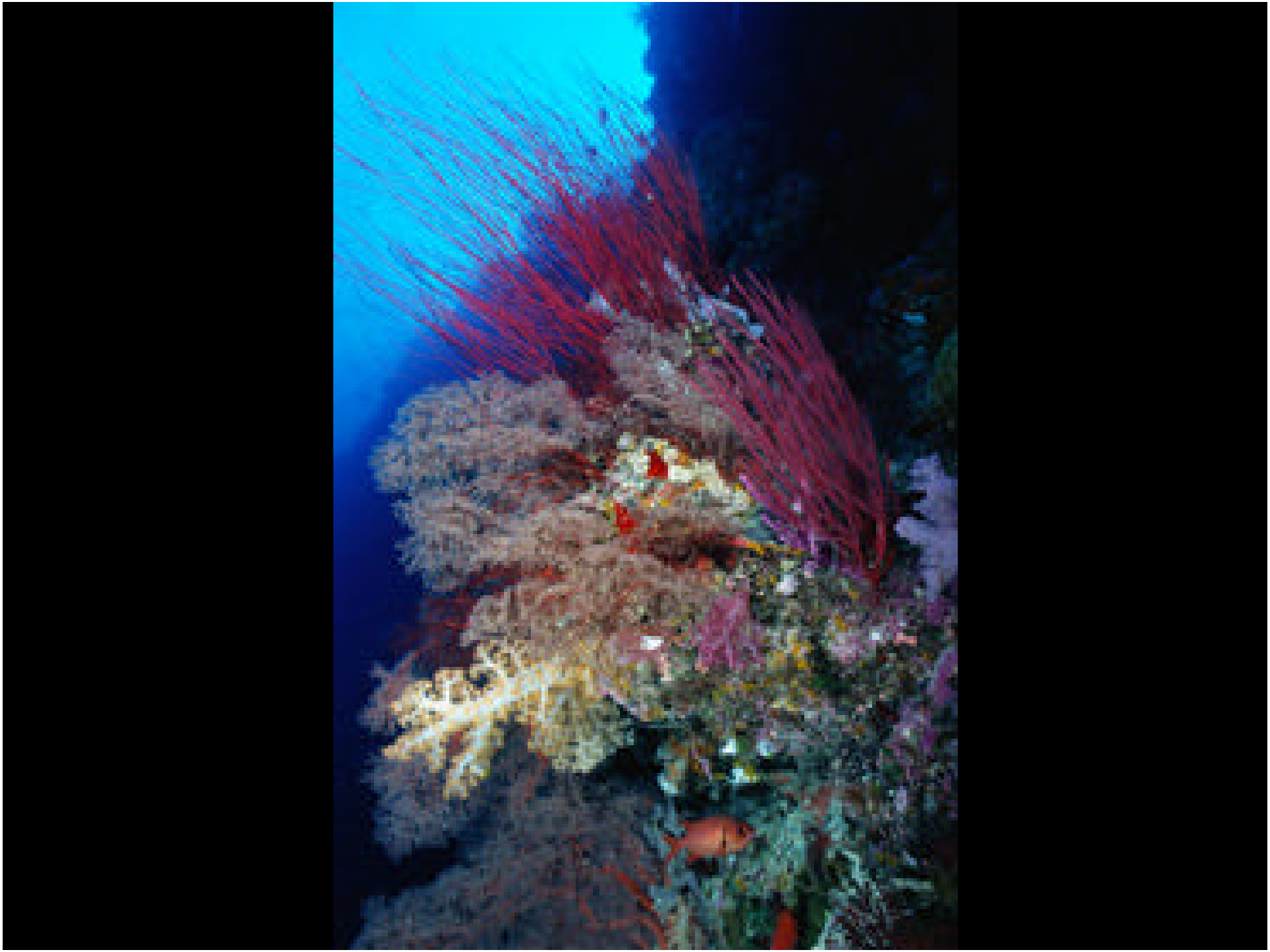


Planetary Biology



- Initial Conditions
- Pre-Living Organic
- Origin of Genetic Code
- Origin of Life
- Evol. of Life & Intelligence
- Future of Terrestrial Life??

Need volcanic eruption image




TIME
Looking For Life Out There
LIFE IN THE UNIVERSE
TIME
STARS
Where Life Begins
DISCOVER
IS ANYONE OUT THERE?
The Economist
Is anybody there?
DISCOVER
LIFE IN SPACE


LIFE ON MARS

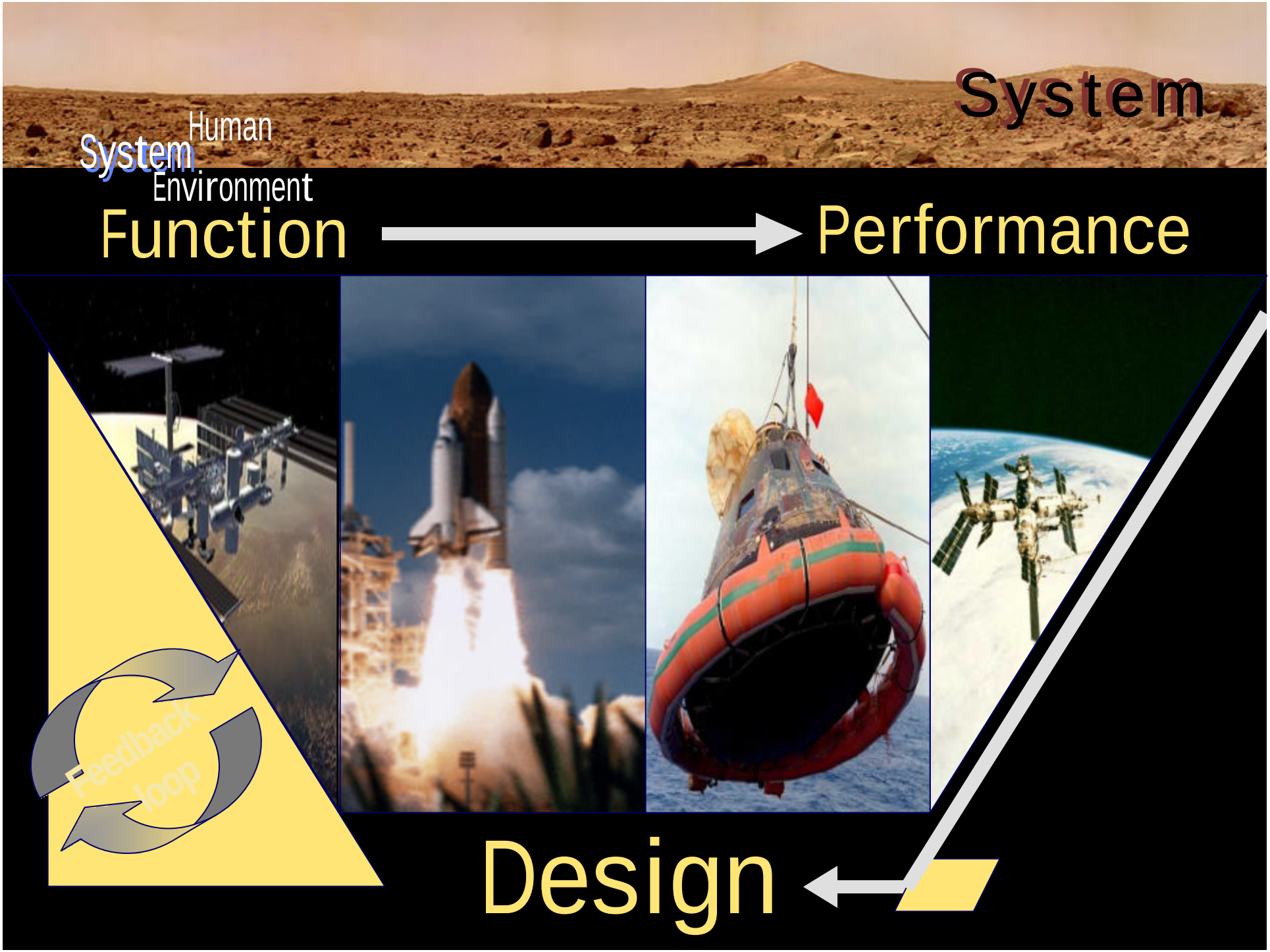

TIME
IS ANYBODY OUT THERE?

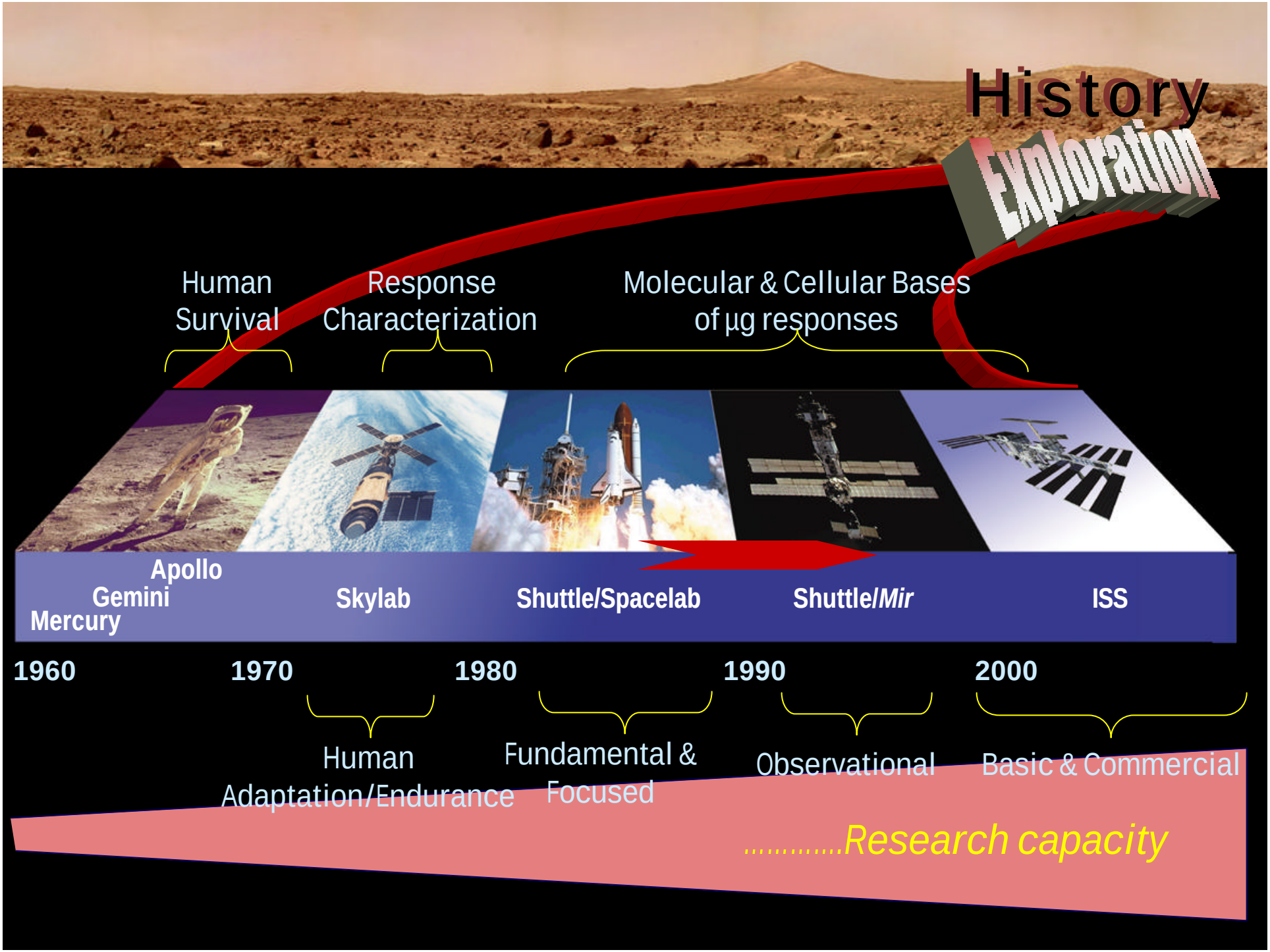

SCIENTIFIC AMERICAN
MAGNIFICENT COSMOS


LIFE
THE WORLD WE LIVE IN: PART XIII
THE STAR-STUDDED REACHES OF MEASURELESS SPACE
20 CENTS
DECEMBER 20, 1954


LIFE
The Search for a Real E.T.

INSPIRATION IS IMPORTANT


System
Human
System
Environment
Function
Performance
Feedback
loop
Design

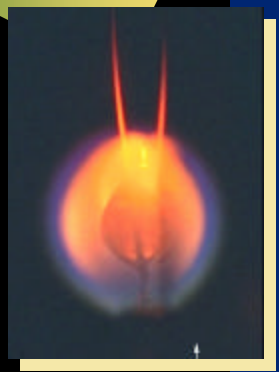

History
Exploration
Human Survival
Response Characterization
Molecular & Cellular Bases of µg responses
Apollo
Gemini
Mercury
Skylab
Shuttle/Spacelab
Shuttle/Mir
ISS
1960
1970
1980
1990
2000
Human Adaptation/Endurance
Fundamental & Focused
Observational
Basic & Commercial
Research capacity

Function

System
Human
Environment

The System is chosen to fulfill a function. This function includes mission objectives and crew protection.

- **Life support**
- **Environmental control**
- **Radiation shielding**
- **Medical capability**



Underlying research

Fluids management

Materials research

Combustion science (fire suppression)

Gravitational biology (biomass production)

Biological interface

Performance

System Human Environment

Performance parameters are chosen to optimize system and crew function.

- **System performance parameters/limits**
- **Standard operating procedures**
  - Vehicle/habitat operations
  - Maintenance procedures
  - Health risk minimization
  - Work/rest cycles

Design

System Human Environment

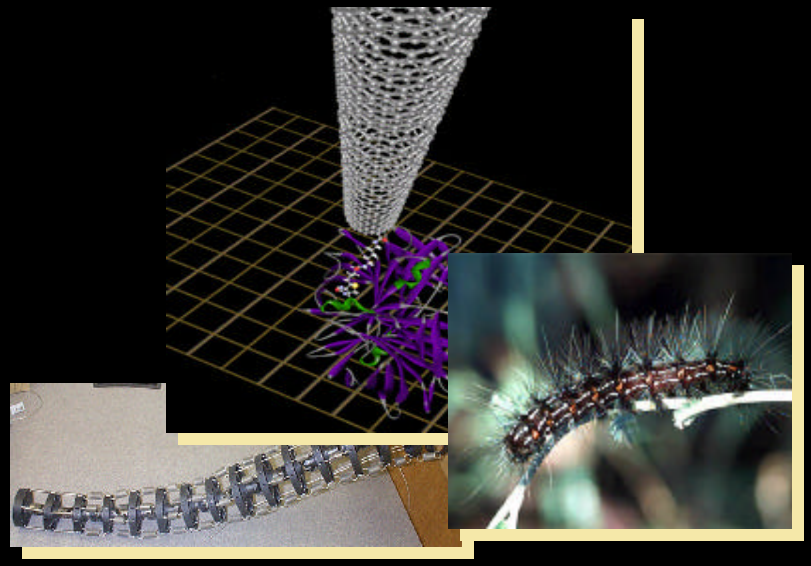
System design needs to accommodate constraints on available power; mass; and crew size, expertise, and availability.

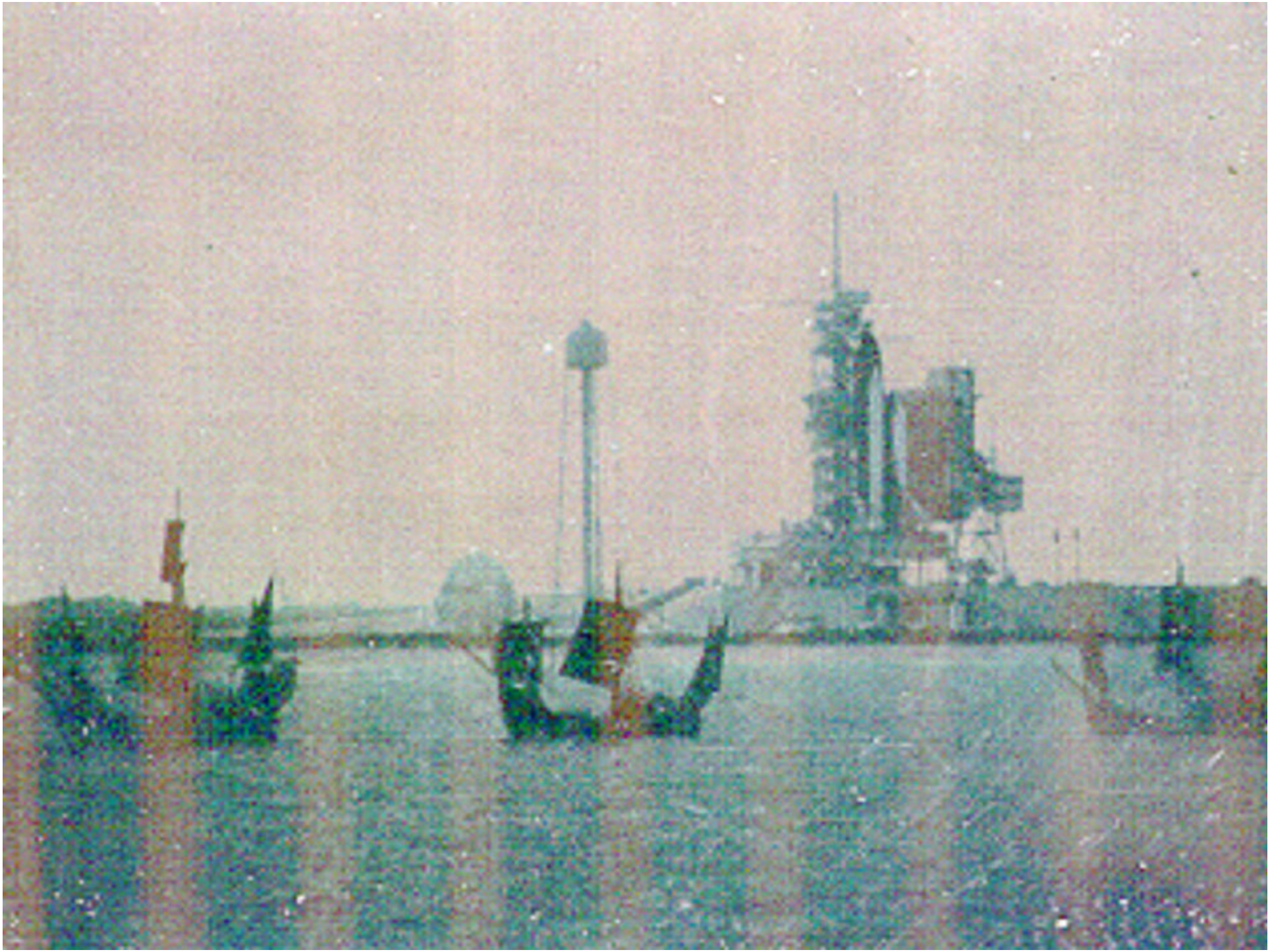
- **Miniaturization**
- **Autonomy**
- **Redundancy**

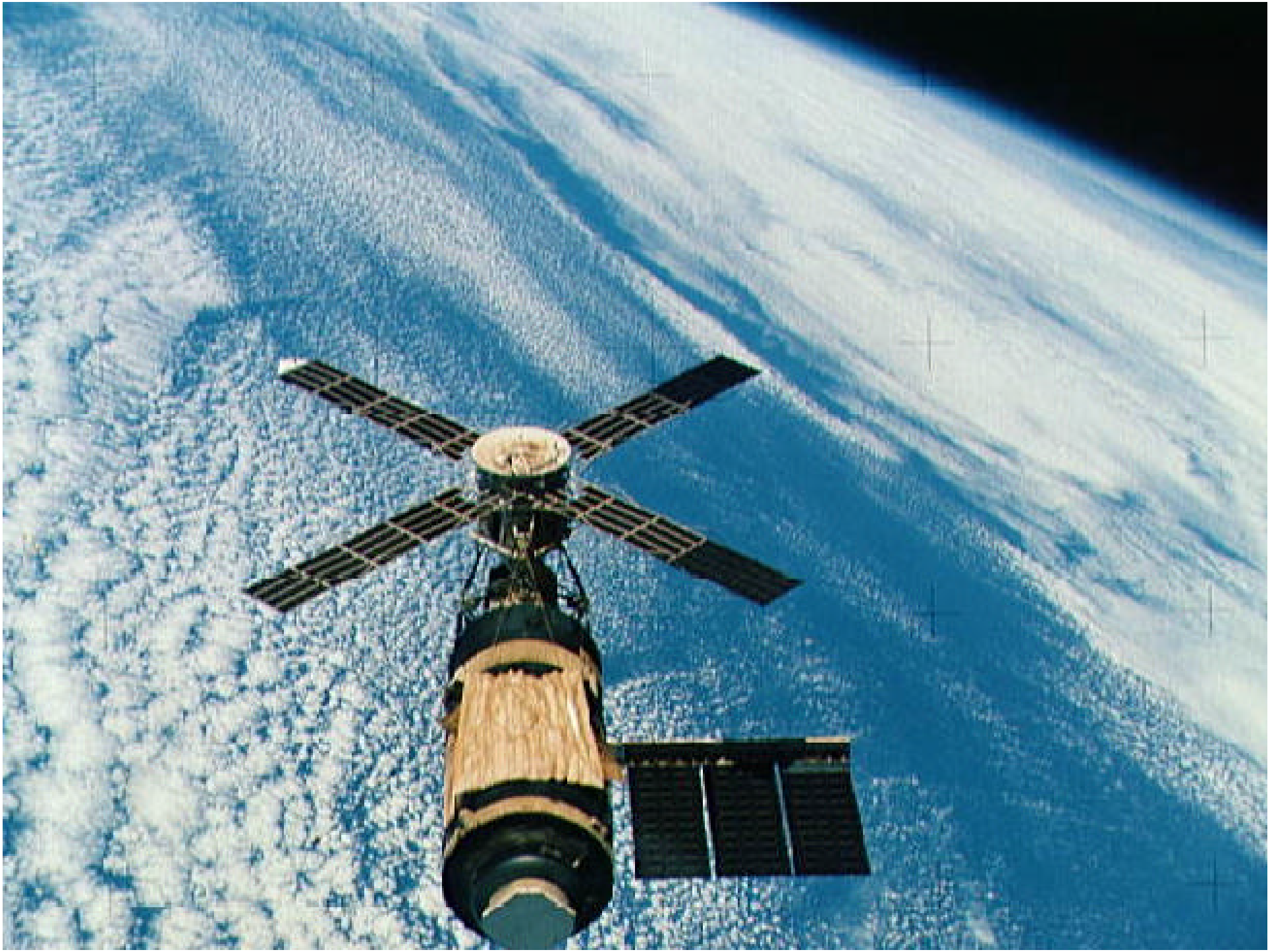
Biologically-inspired technologies

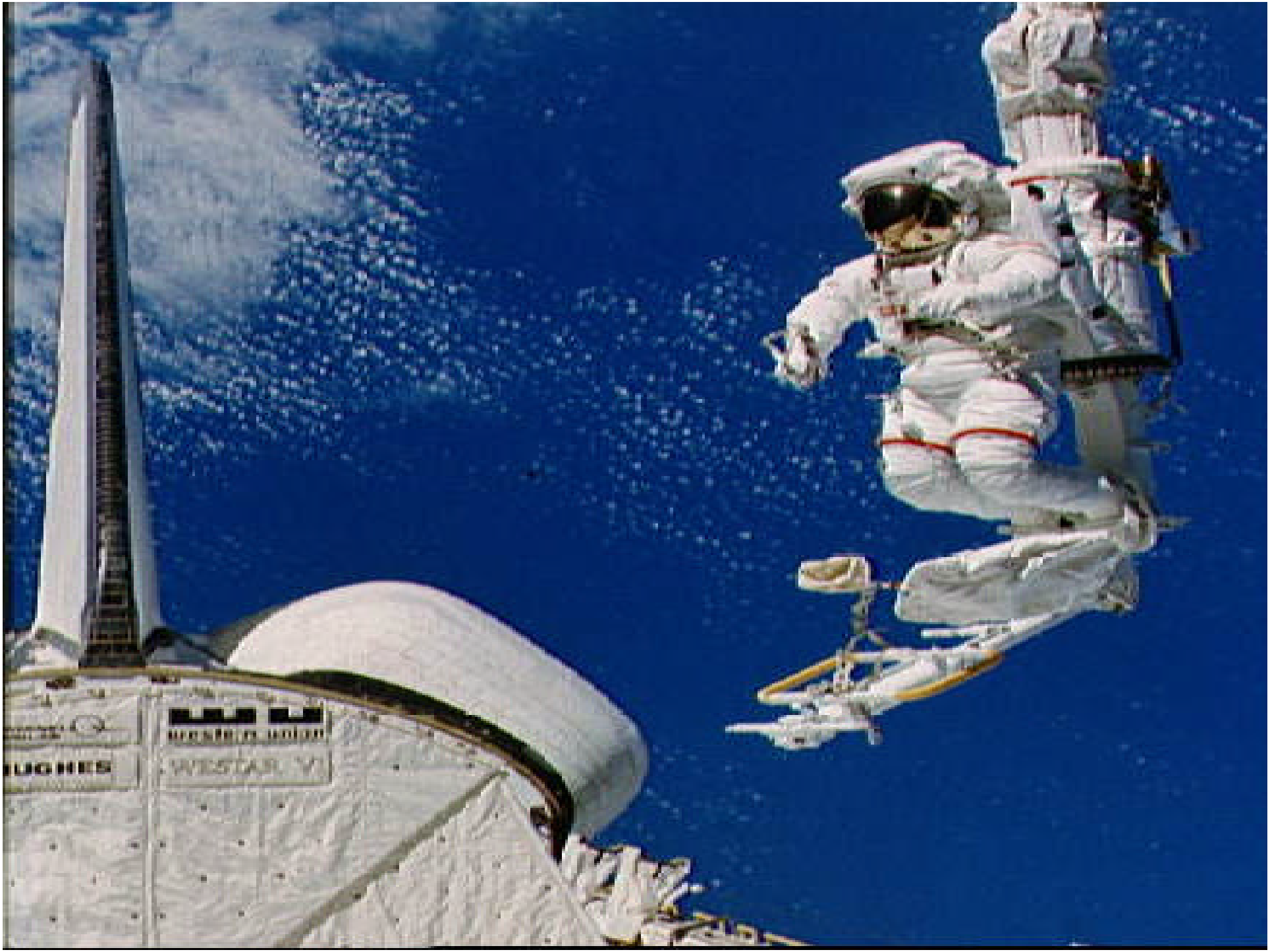
- **Accessibility**
- **Ease-of-use**
- **Emergency procedures**

Human factors








WESTAR VI

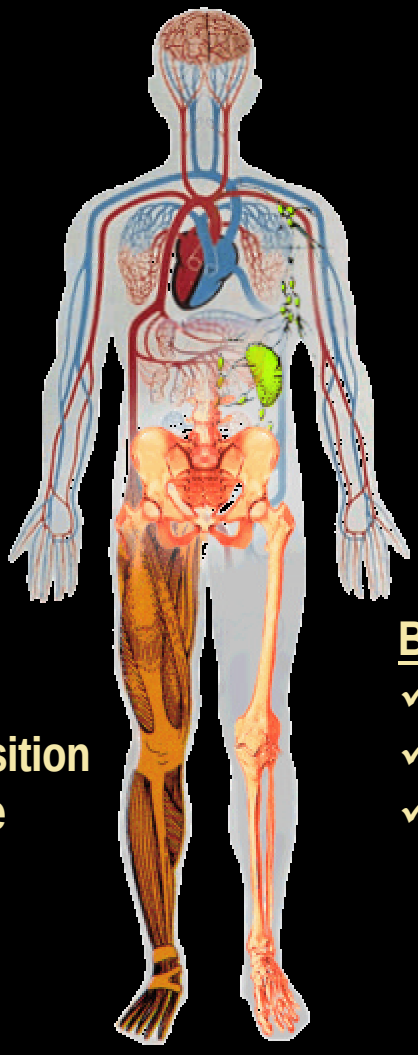
Medical Care Delivery in the Extreme Environments of Space

Prerequisites for Human Survival in Extreme Environments

Environment	*Life Support*
Arctic/Antarctic	*Clothing and Shelter (convection)*
Desert/Tropics	*Clothing and Shelter (convection and radiation)*
Mountain	*Supplement Oxygen*
Saturation Diving	*Closed Environment*
Space	*Closed Environment*

Medical Care Delivery in the Extreme Environments of Space

Effects of Environmental Variables on Organ Systems



Nervous
- ✓ Pressure
- ✓ Gas Composition
- ✓ Gravity
- ✓ Temperature

Circulatory
- ✓ Pressure
- ✓ Gas Composition
- ✓ Gravity
- ✓ Temperature
- ✓ Humidity

Blood
- ✓ Gas Composition
- ✓ Gravity

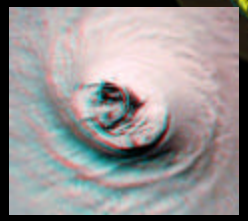
Muscle
- ✓ Gravity

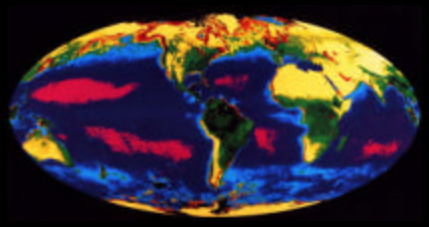
Pulmonary
- ✓ Pressure
- ✓ Gas Composition
- ✓ Temperature
- ✓ Humidity

Bone
- ✓ Pressure
- ✓ Gas Composition
- ✓ Gravity

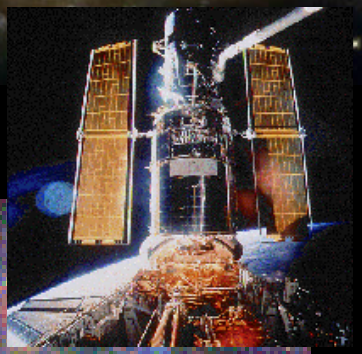
NASA Science

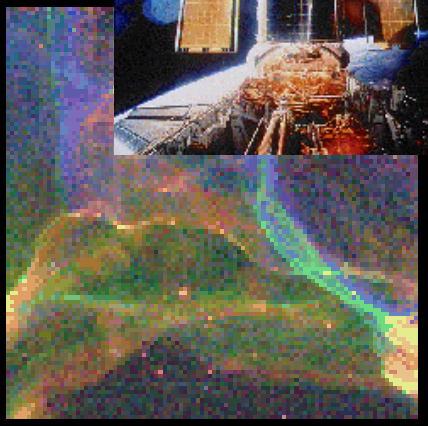
FROM
Space





ABOUT
Space





IN
Space

Programs

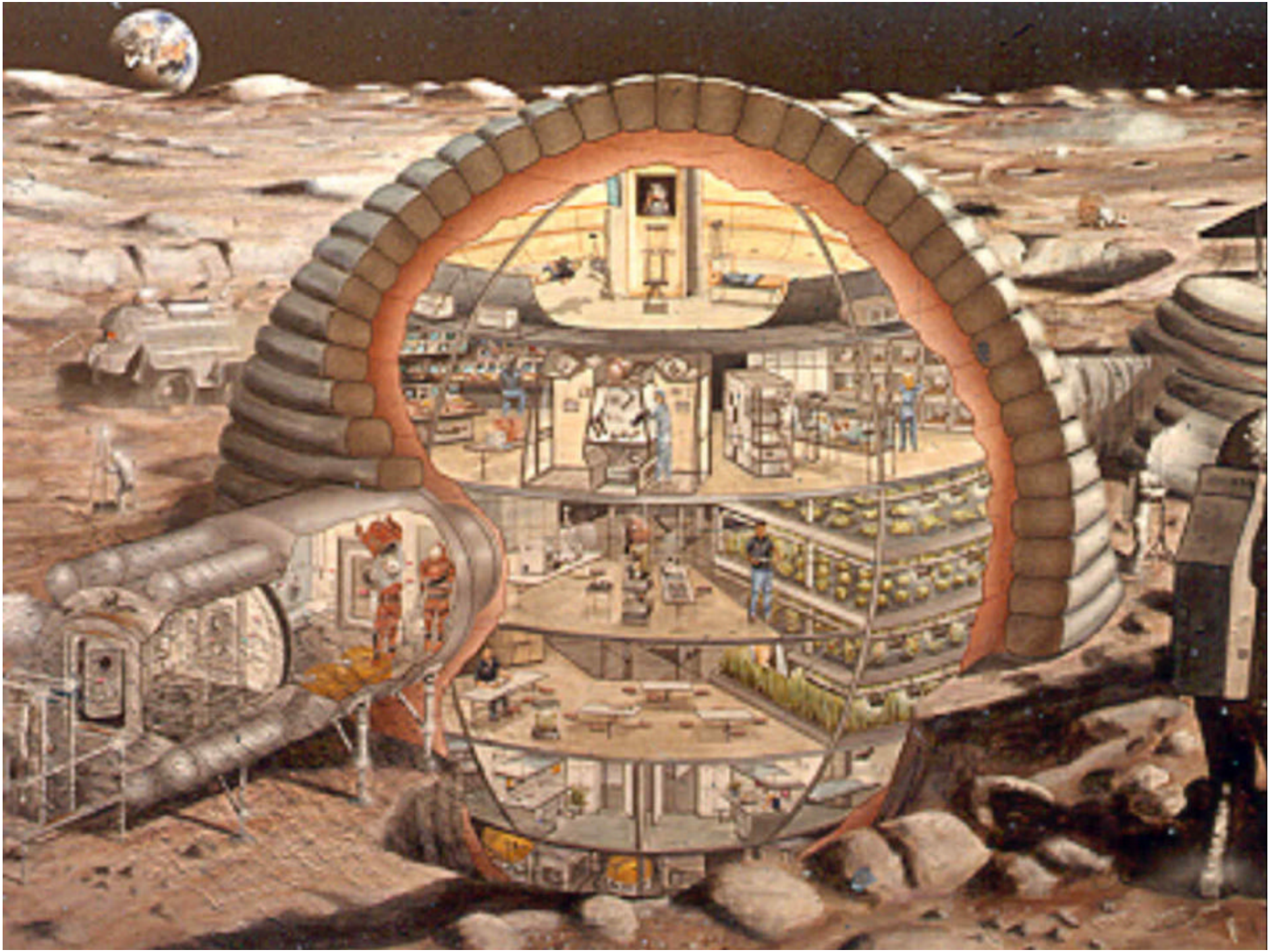
Understanding the role of Gravity

dose ↔ response

Use the space environment for research
- **Physics**
- **Chemistry**
- **Biology**
- **Engineering**

Facilitate the commercial use of space
- **Products**
- **Services**

Enable safe human exploration
- **Countermeasures**
- **Life support**
- **Medical care**



CONSEQUENCE OF FANTASY: BANKRUPTCY

Medical Care Delivery in the Extreme Environments of Space

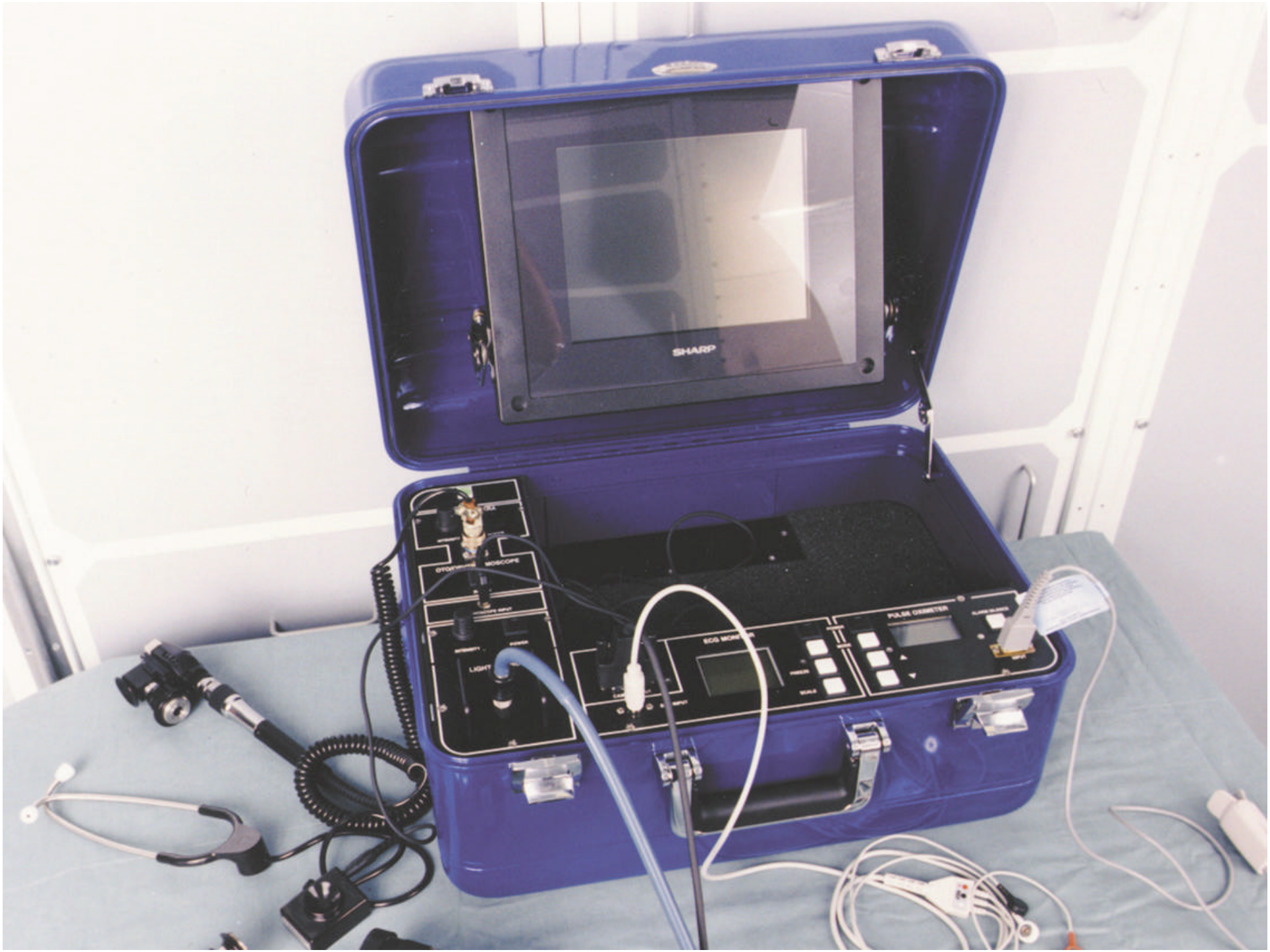
Extreme Environments

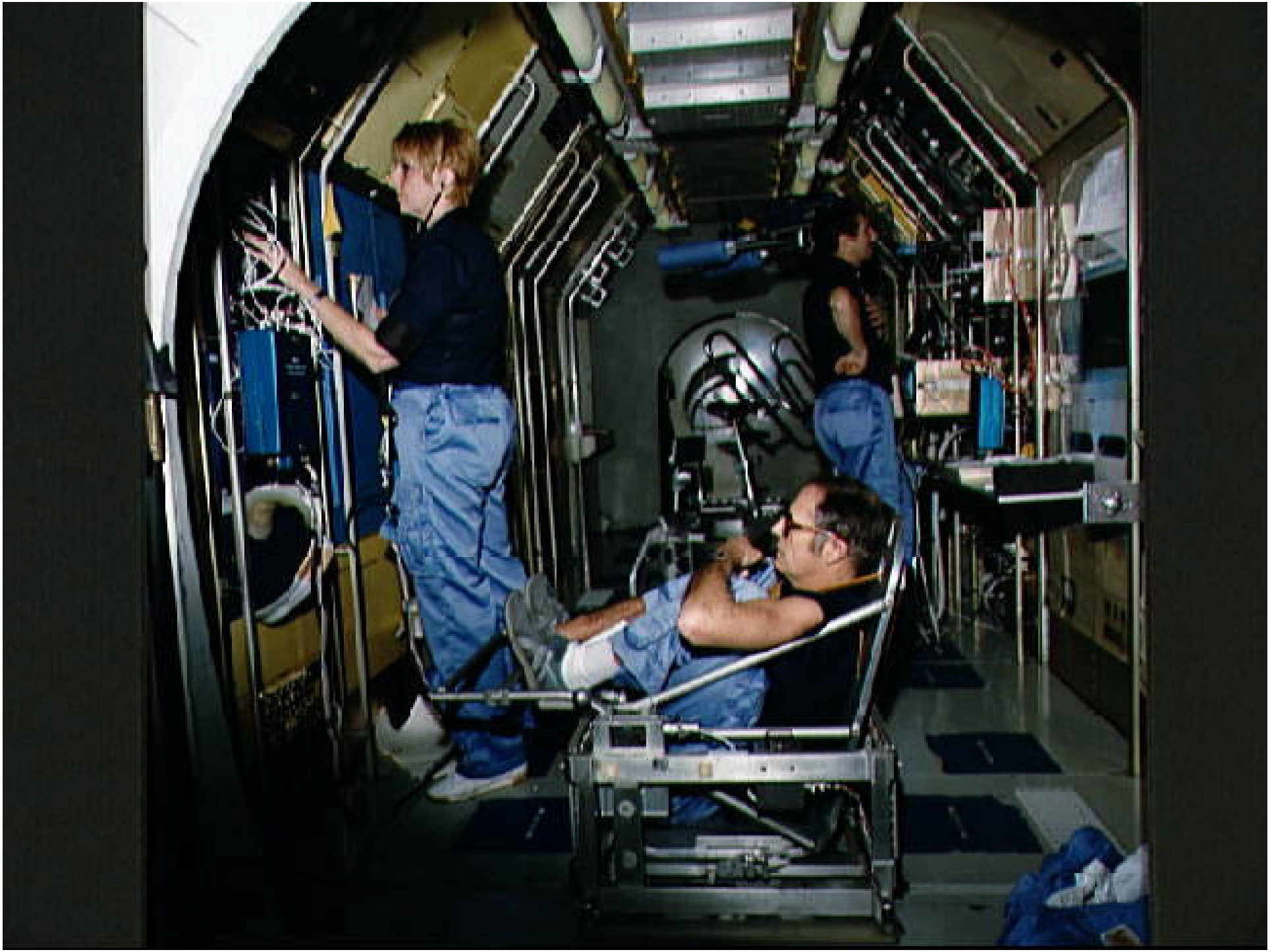
- *Desert*
- *Tropics*
- *Underwater Habitats*
- *Arctic and Antarctic*
- *Low Earth Orbit*
- *Moon*
- *Deep Space*

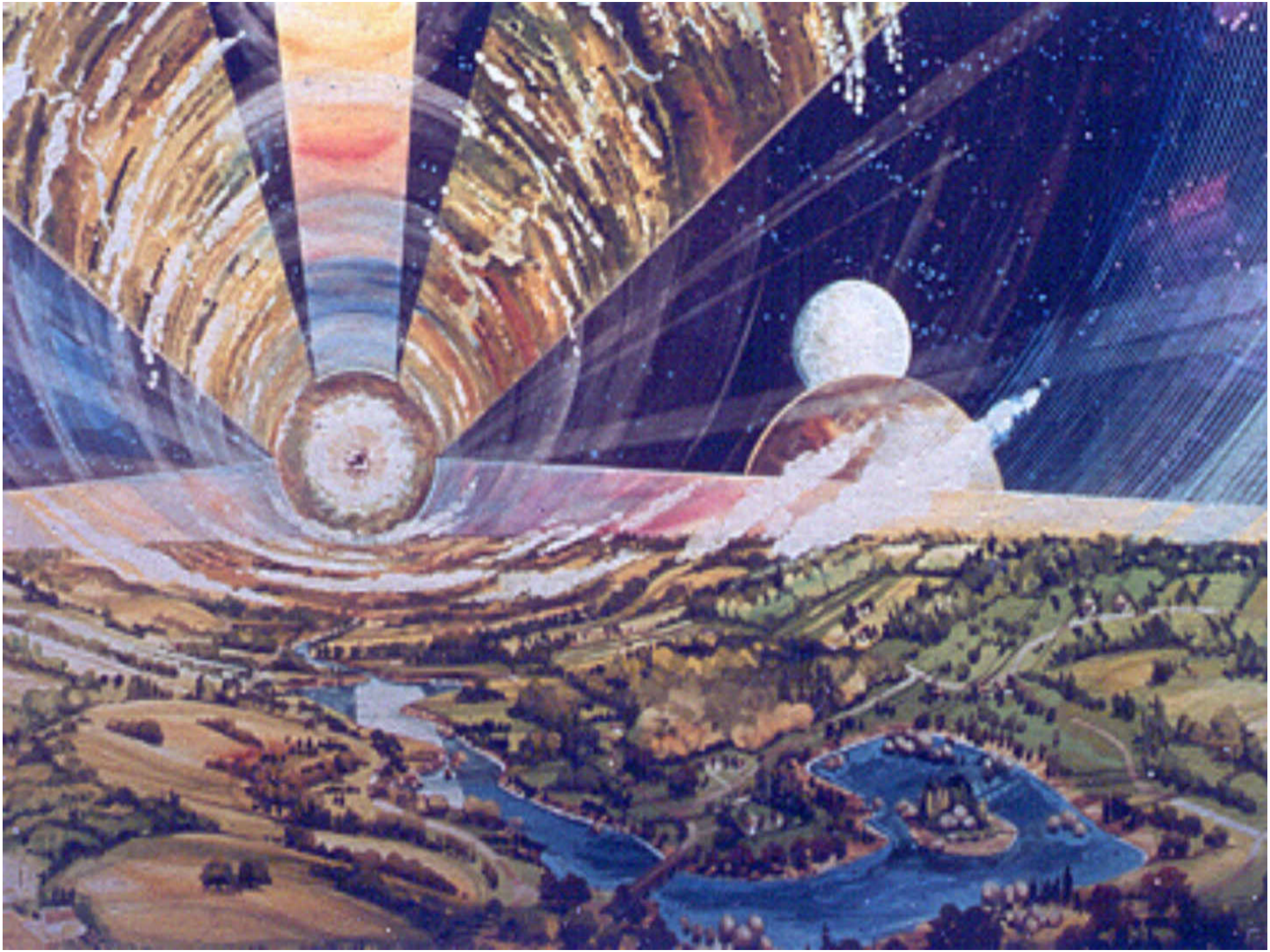
Medical Care Delivery in the Extreme Environments of Space

Common Characteristics of Space Analogs

- *Remoteness/Isolation*
- *High Maintenance*
- *Mission Duration*
- *Limited Resupply*
- *Limited Communications*
- *Physical Danger*
- *No Immediate Access to Definitive Medical Care*
- *Circadian Cues*
- *Confined Space*
- *Cultural Differences*
- *Limited Power*
- *Autonomous Operations*
- *Psychosocial Factors*
- *Physiological Consequences*


SHARP
LIGHT
ECG MONITOR
PULSE OXIMETER





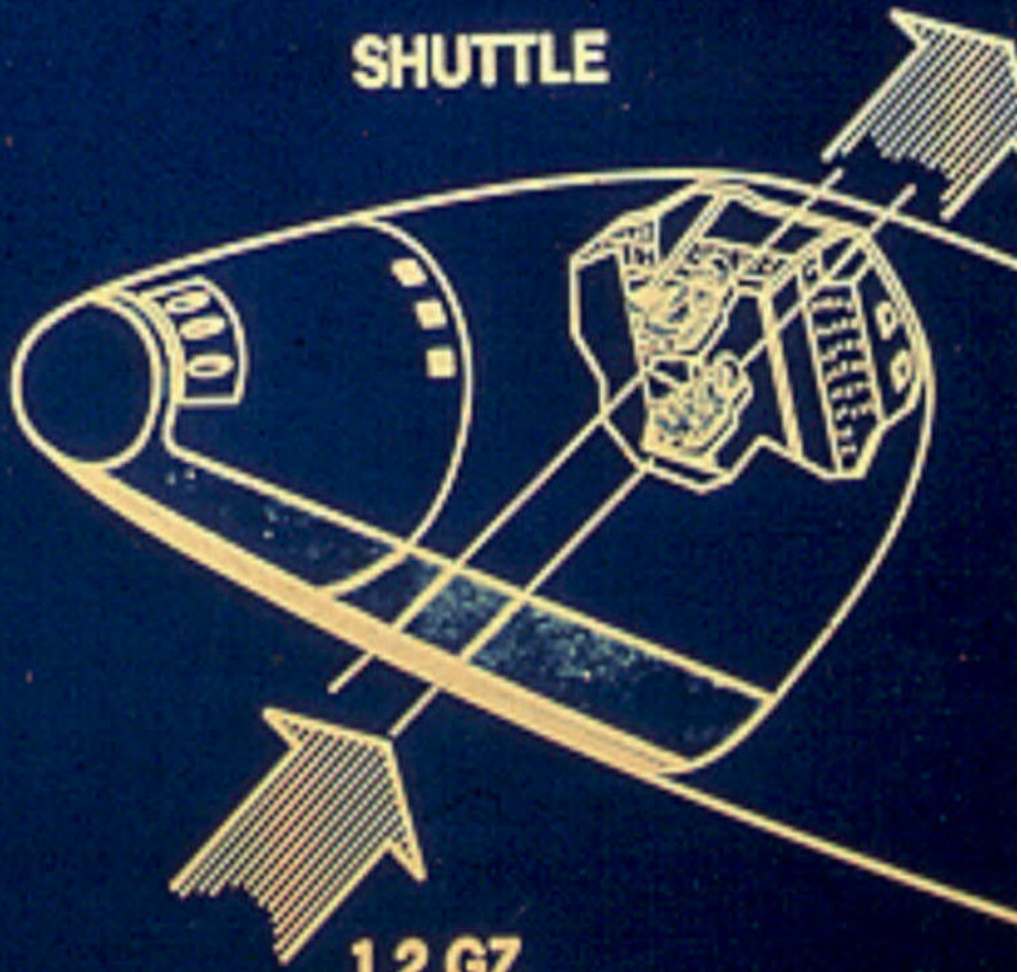
REENTRY G

NASA
Life Sciences

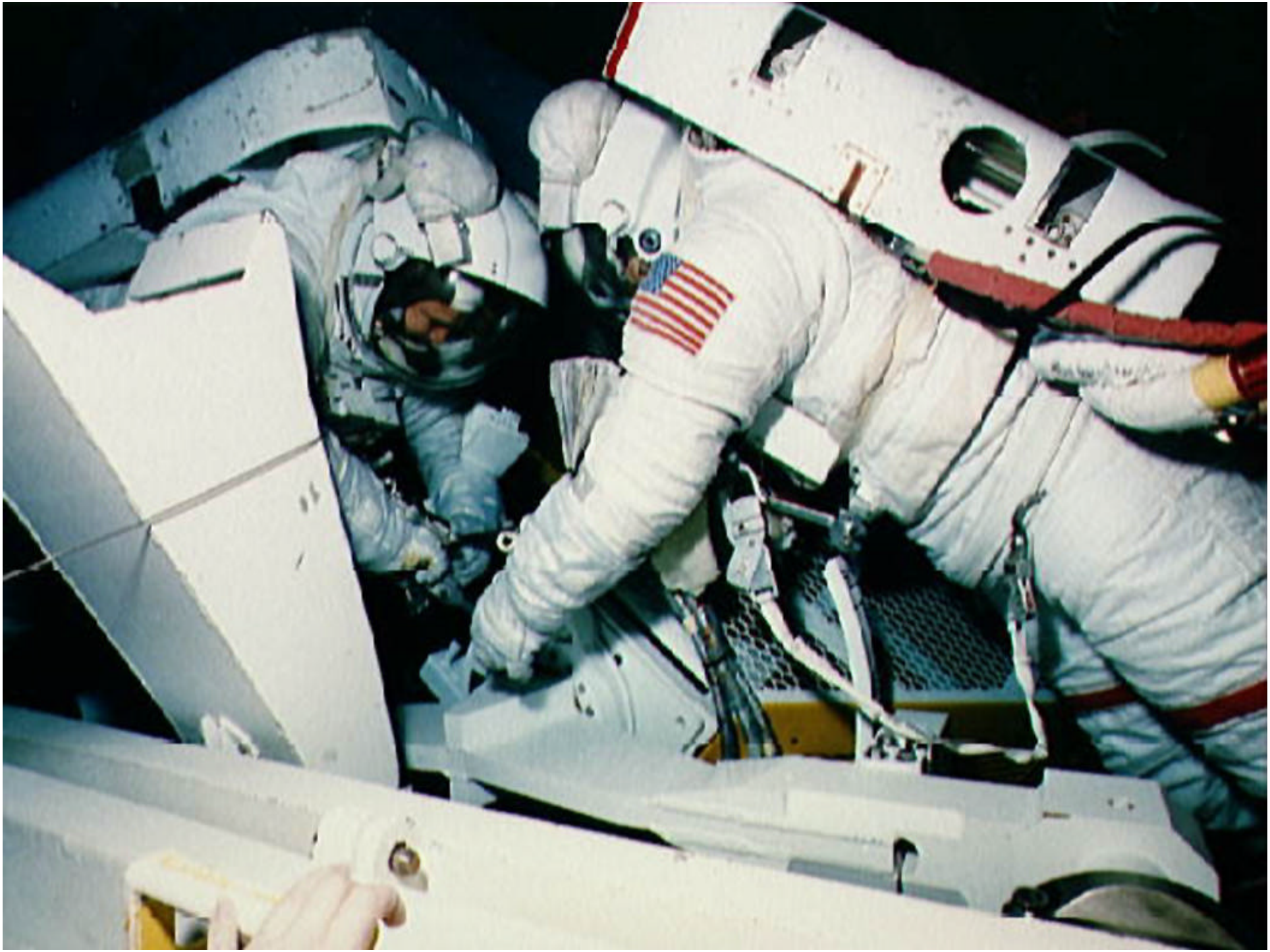
APOLLO

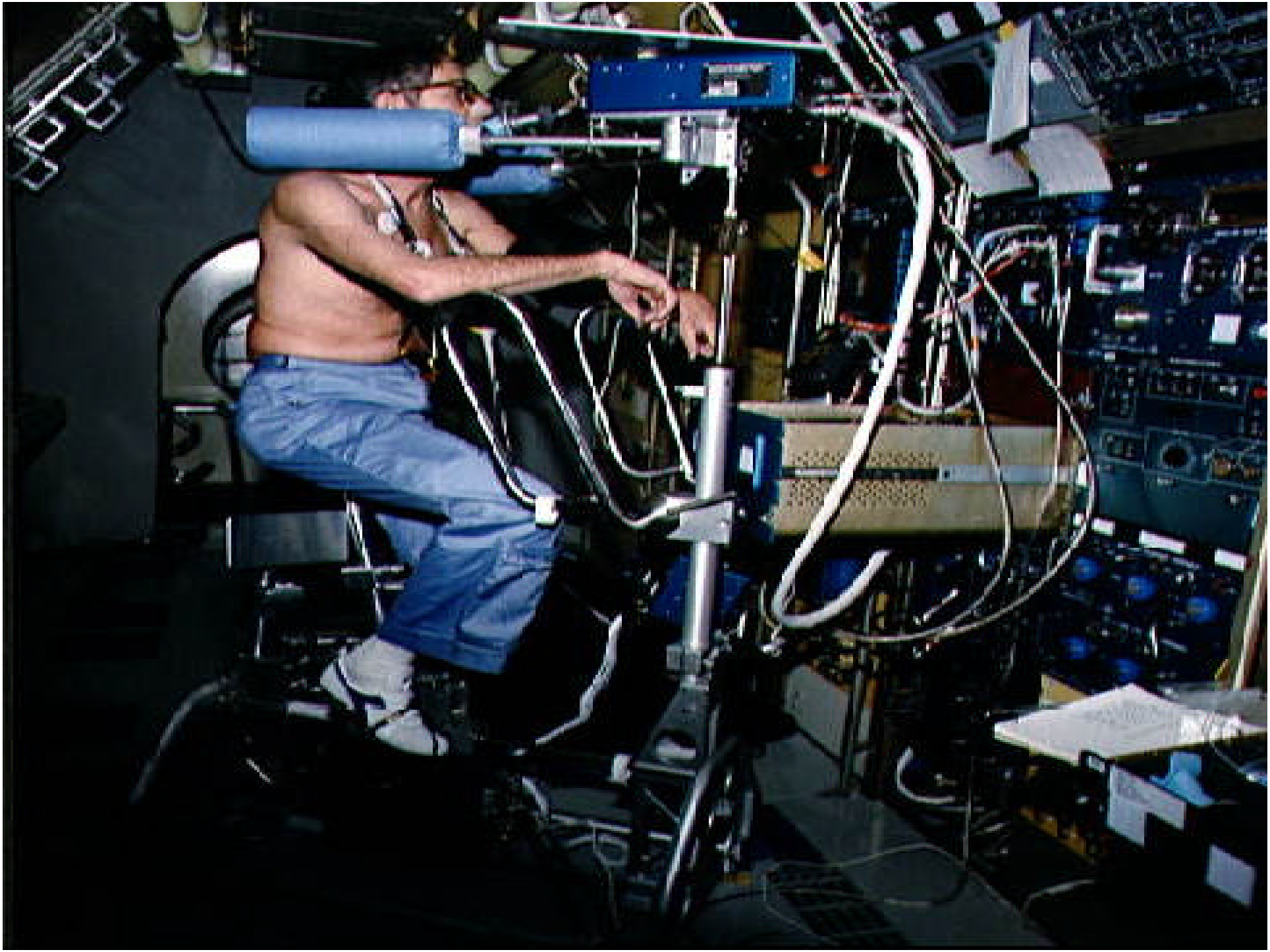
7.19 GX
(1 MIN)

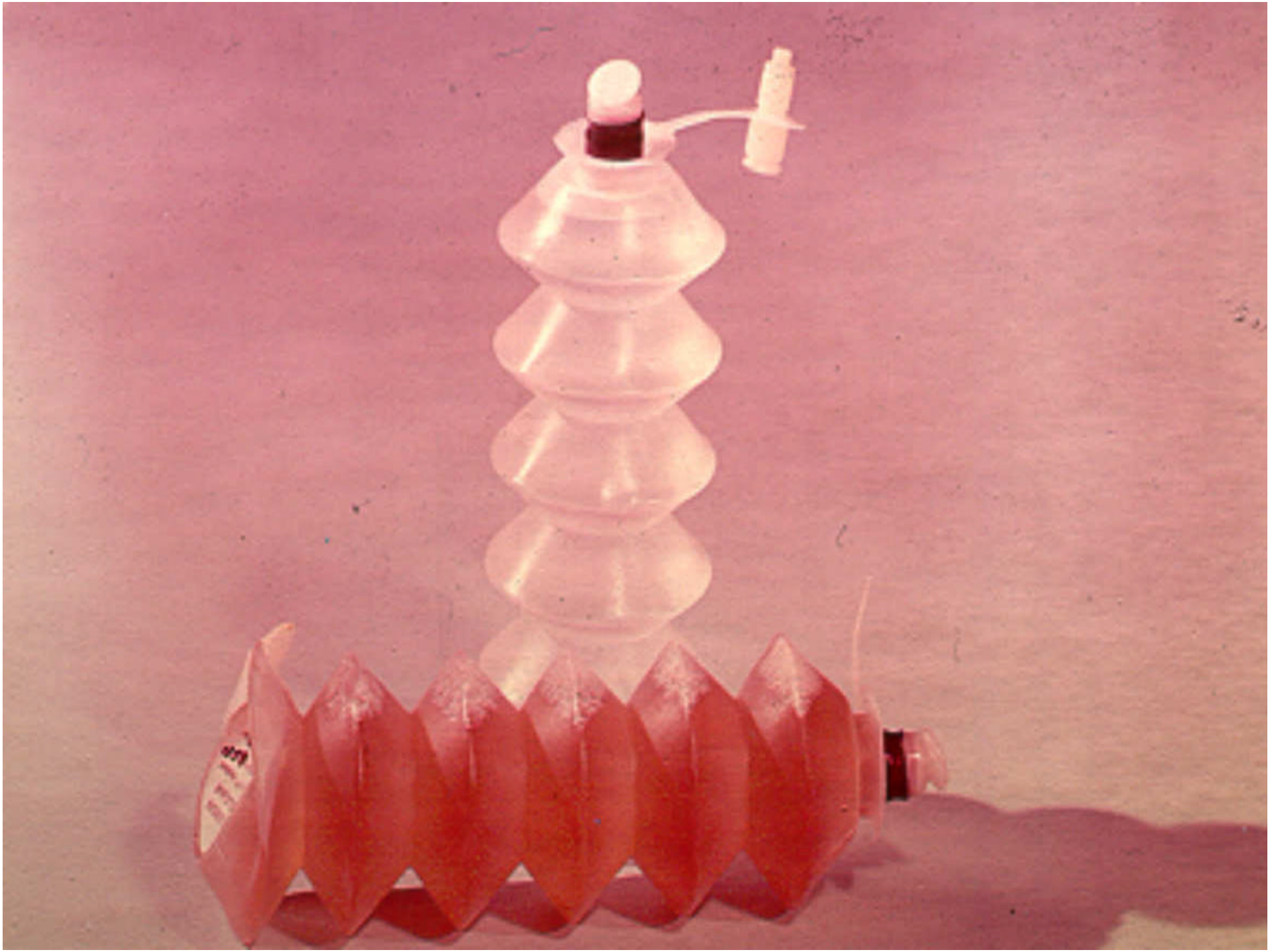
SHUTTLE



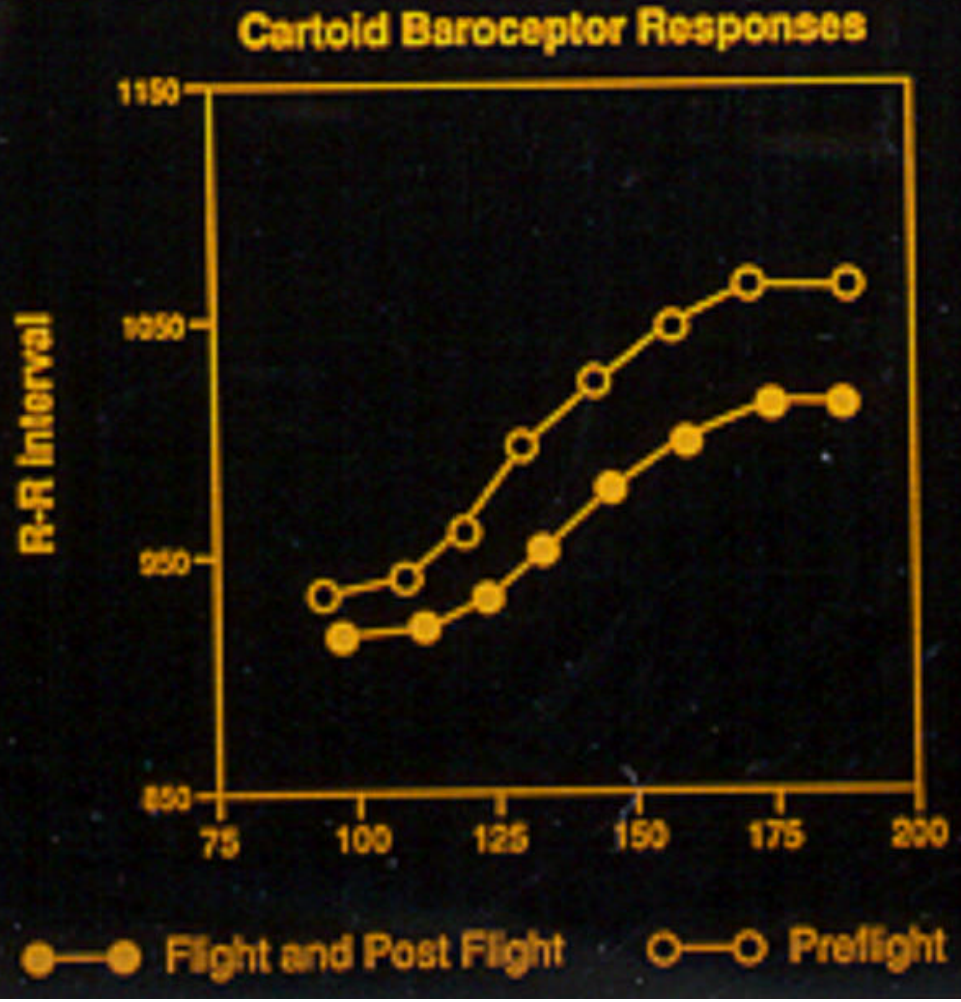
1.2 GZ
(17 MIN)



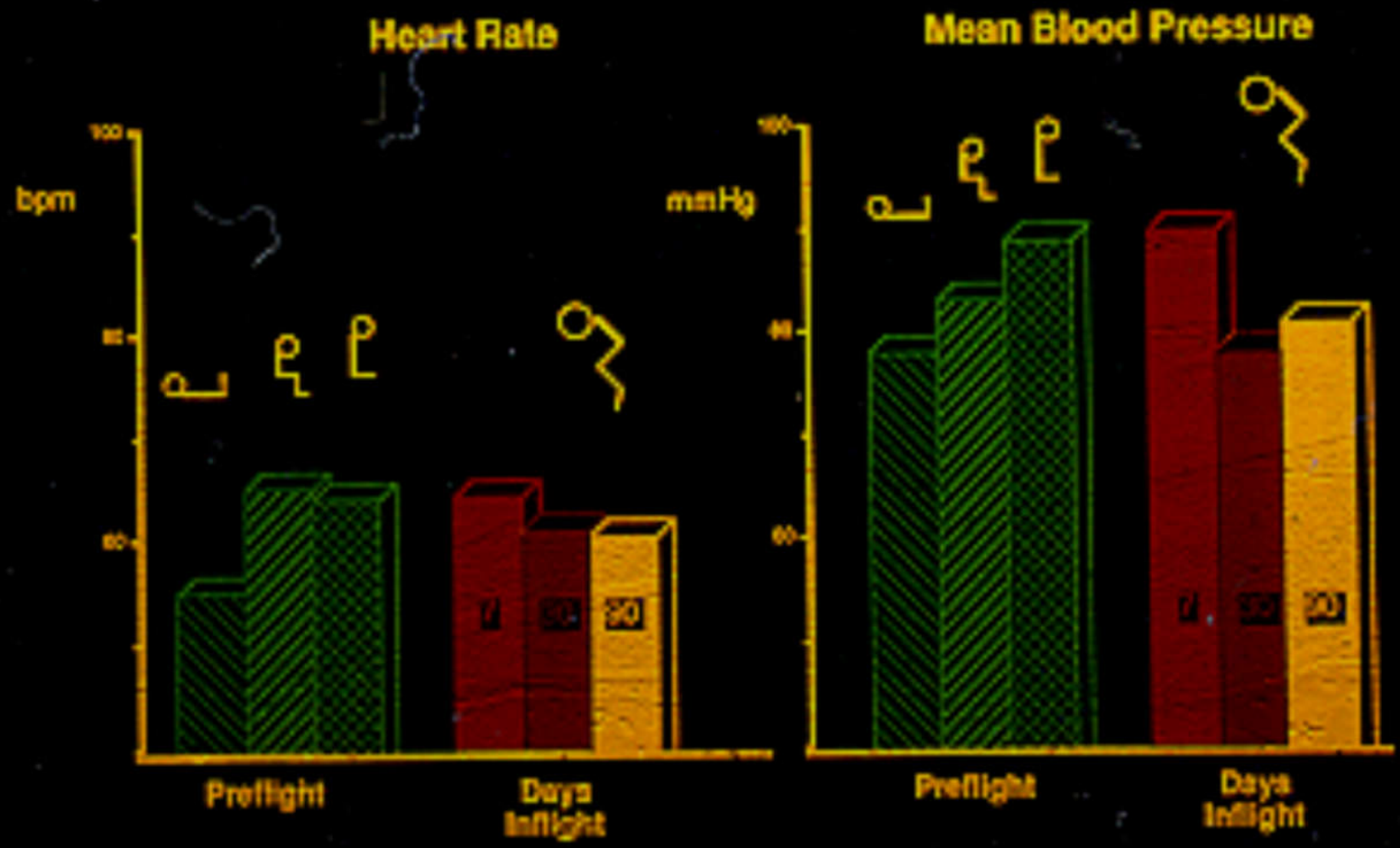


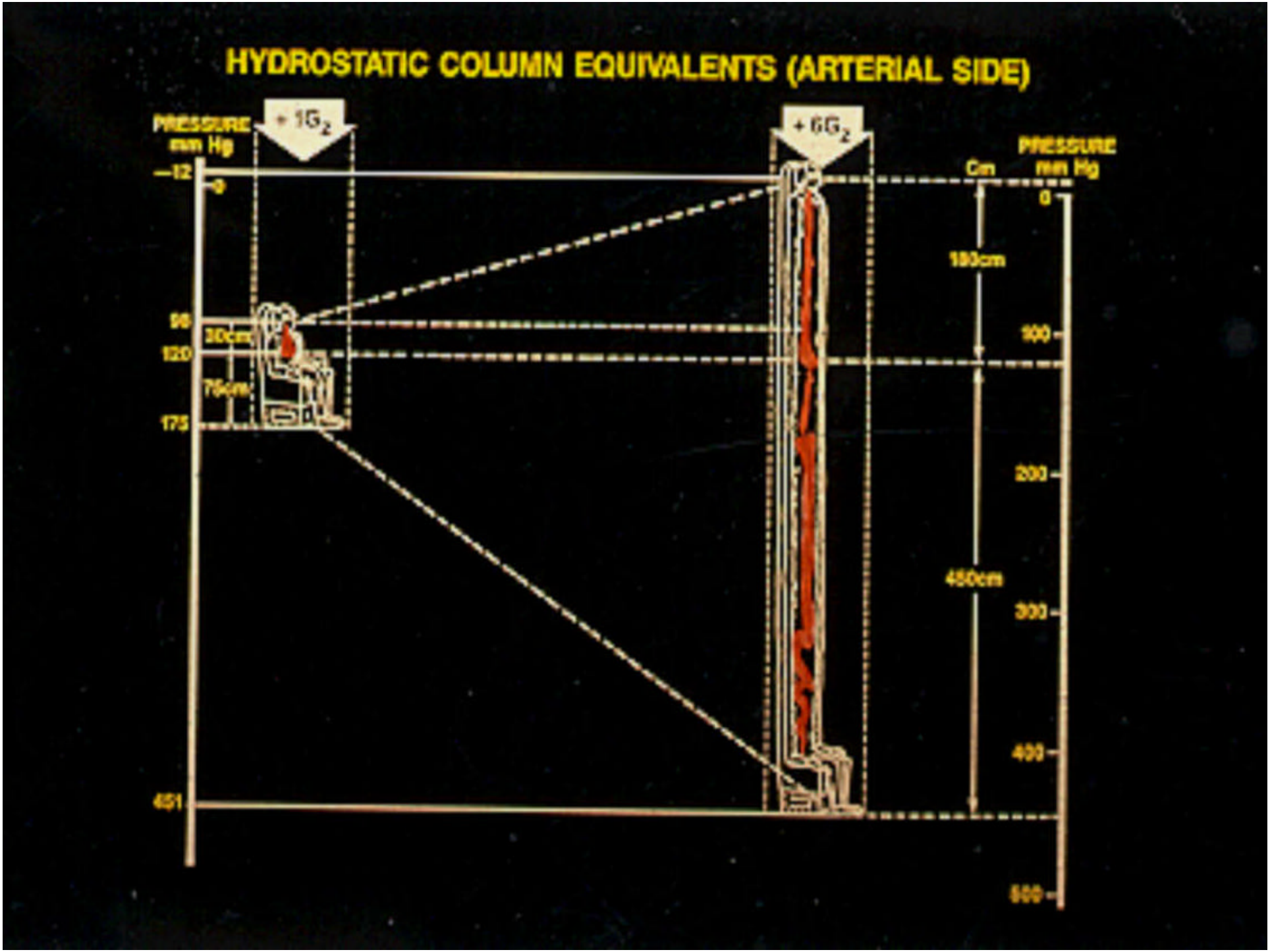


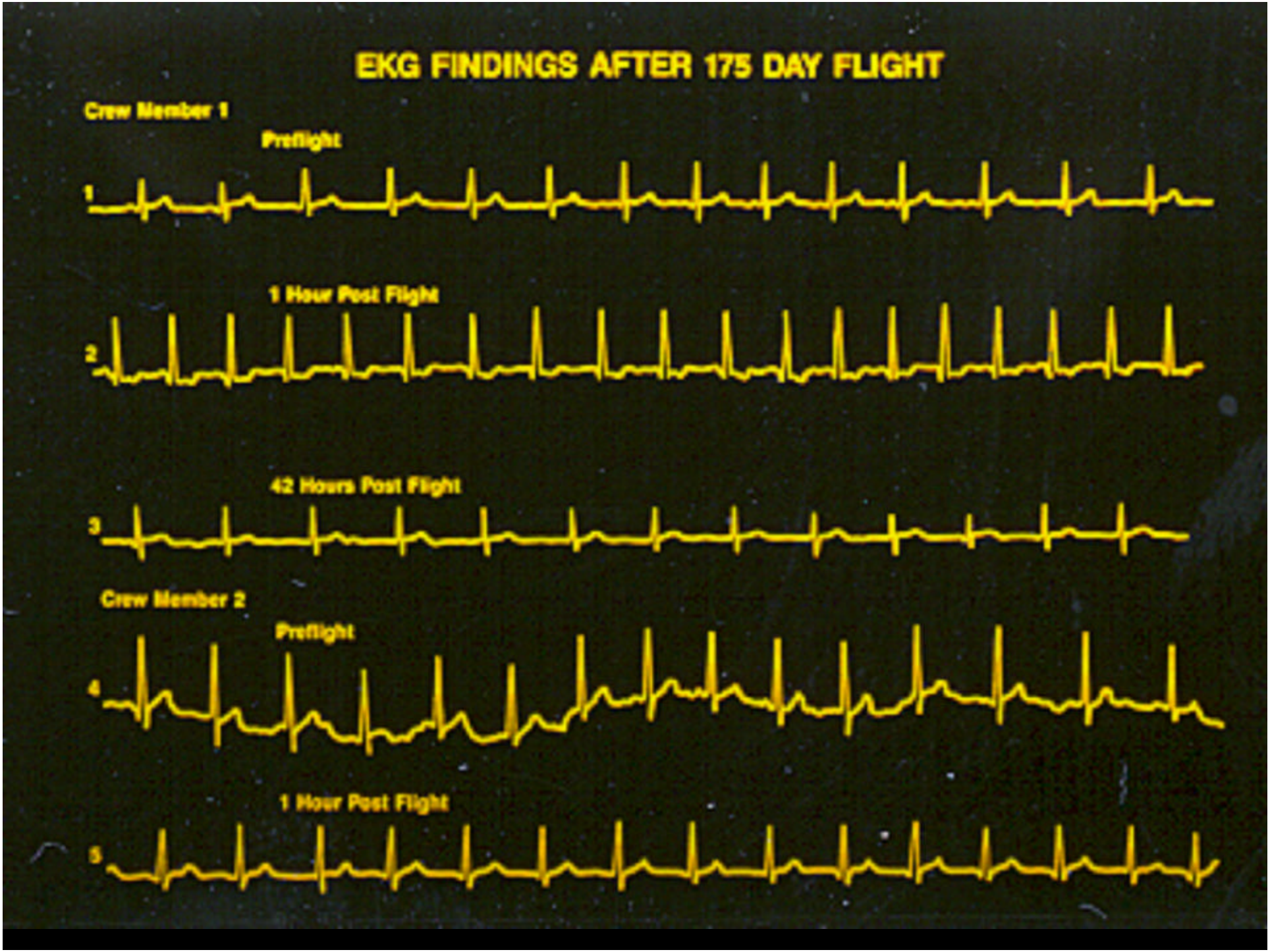
SLS-1 PRELIMINARY RESULTS

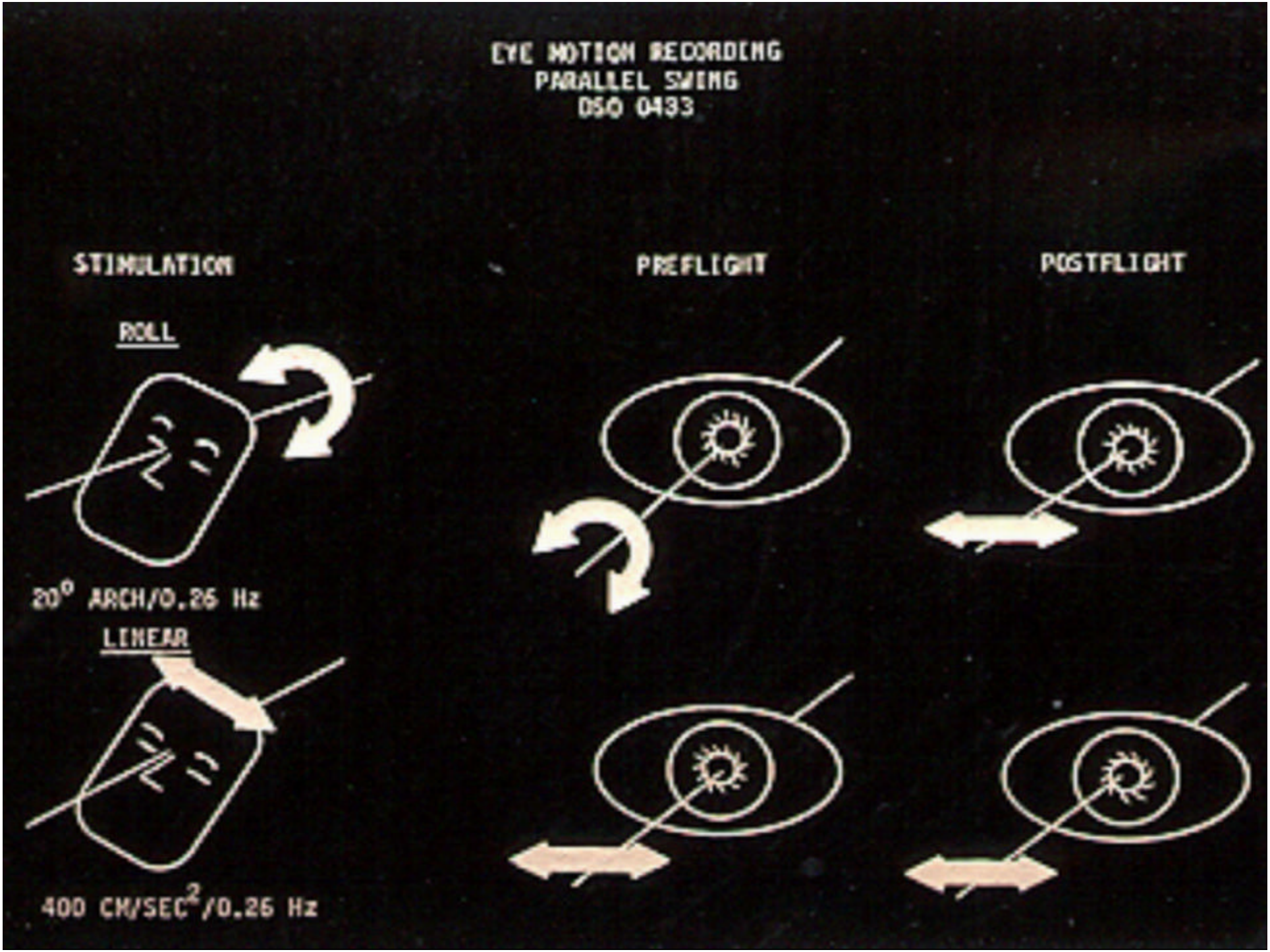


CV CHANGES AS A FUNCTION OF POSTURE AND FLIGHT DURATION



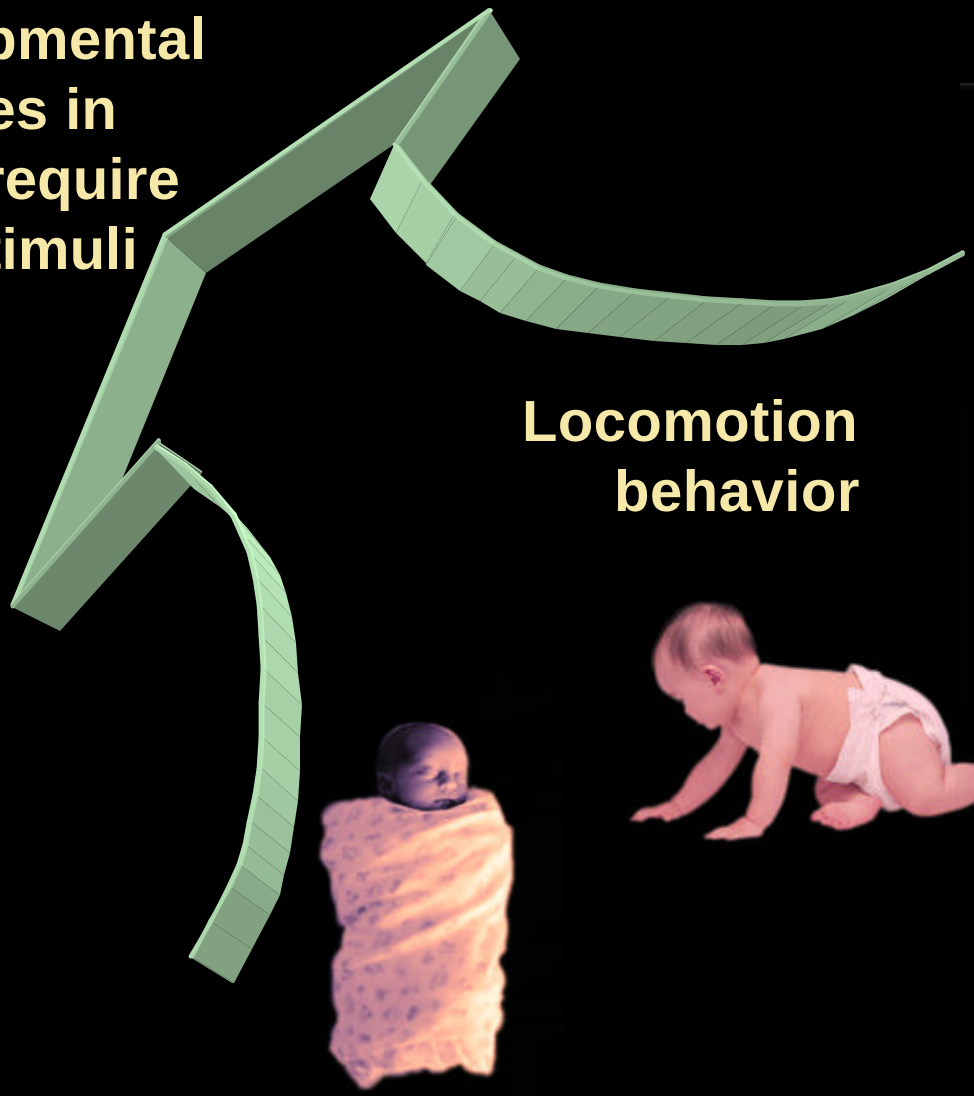

HYDROSTATIC COLUMN EQUIVALENTS (ARTERIAL SIDE)
PRESSURE mm Hg
+1G$_z$
+6G$_z$
PRESSURE mm Hg
Cm
−12
0
0
180cm
98
30cm
100
120
75cm
175
200
450cm
300
400
451
600


EKG FINDINGS AFTER 175 DAY FLIGHT
Crew Member 1
Preflight
1
1 Hour Post Flight
2
42 Hours Post Flight
3
Crew Member 2
Preflight
4
1 Hour Post Flight
5


EYE MOTION RECORDING
PARALLEL SWING
DSO 0433
STIMULATION
PREFLIGHT
POSTFLIGHT
ROLL
20° ARCH/0.26 Hz
LINEAR
400 CM/SEC²/0.26 Hz

Development

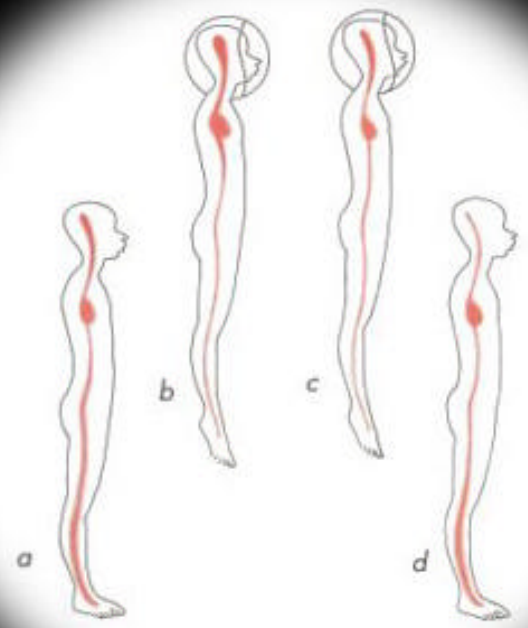
Key developmental processes in mammals require gravity stimuli



Locomotion behavior

Acute fluid shift to 0 g

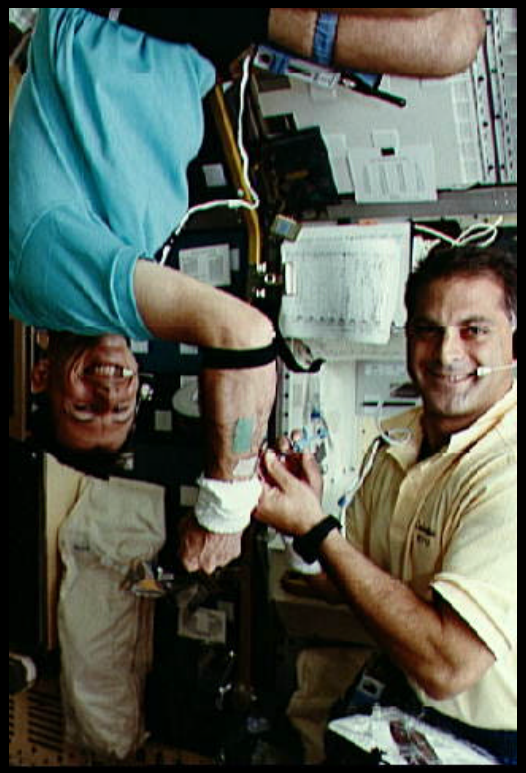
Loss of fluid and adaptation to 0 g



Normal Preflight

Acute recovery in 1g

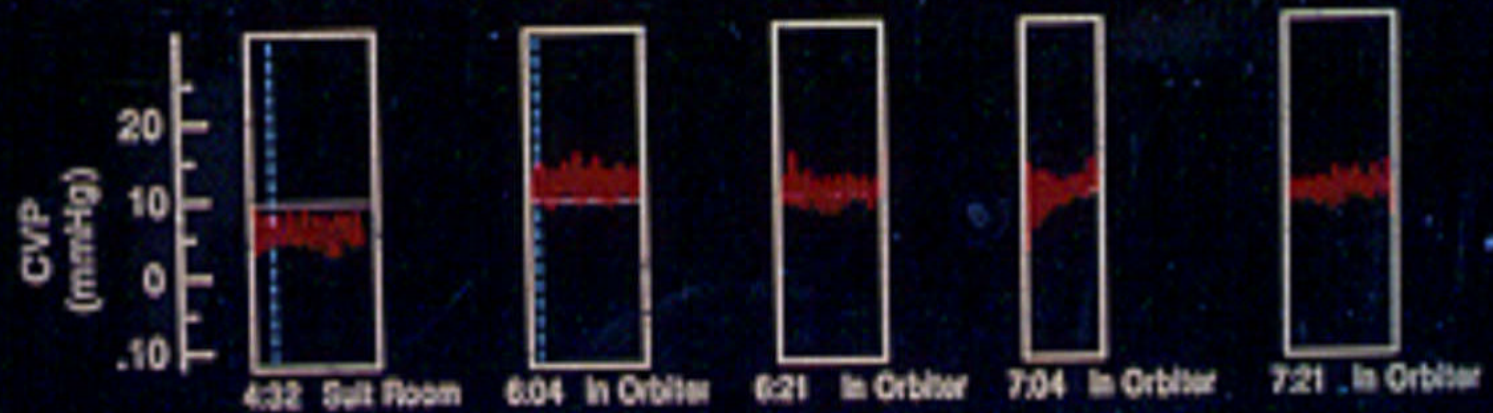
Fluid shift response to microgravity exposure

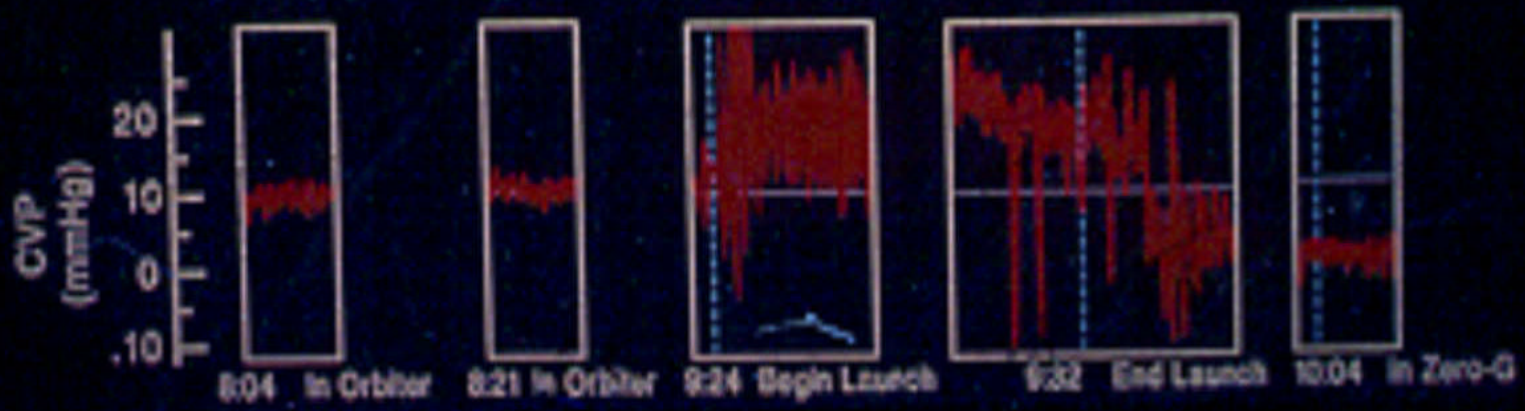


Samples were collected to study fluid volume regulation mechanisms

UT SOUTHWESTERN MEDICAL CENTER

Spacelab Life Sciences - 1

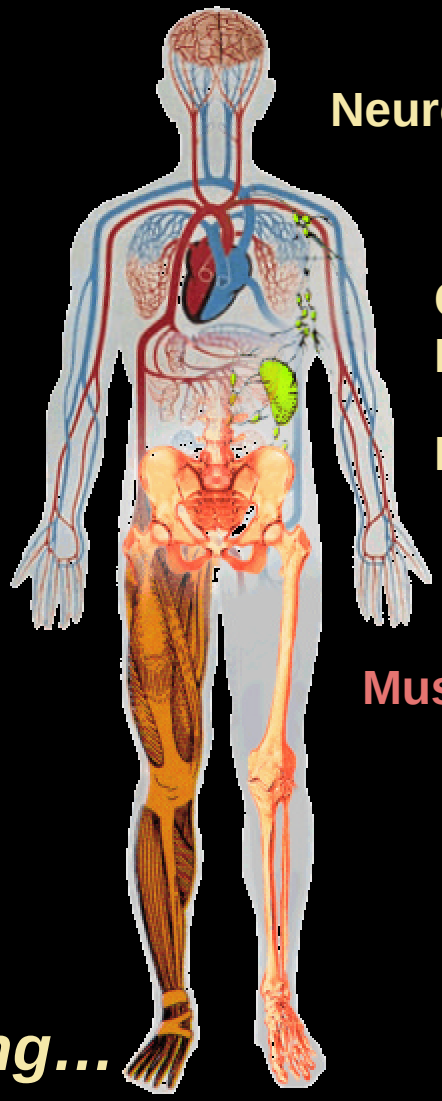




Adaptation

Adaptive

Pathological



Neurosensory & Neuromotor

Cardiovascular/
Pulmonary

Endocrine

Musculoskeletal

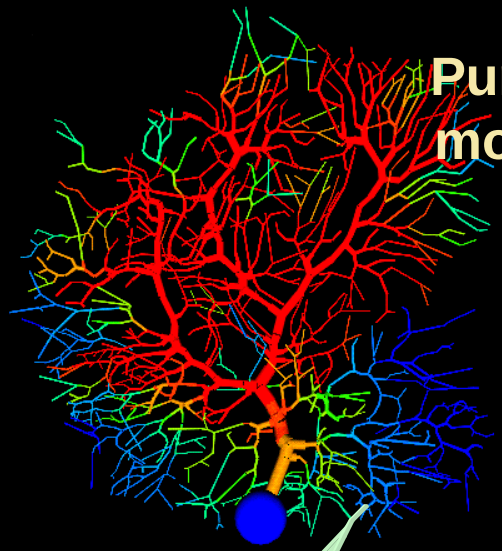
Radiation

Confinement

parallels with aging…

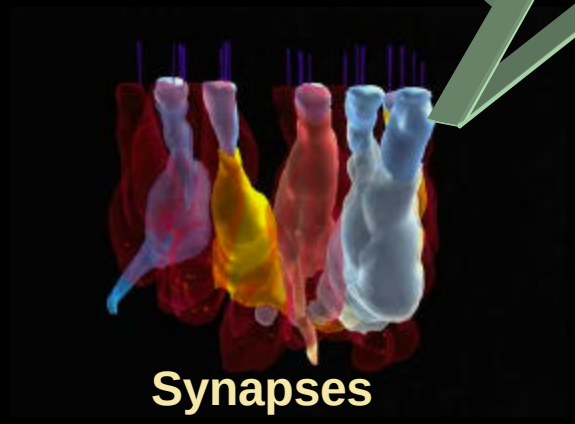
Plasticity

Rapid changes in function and structure to high or low acceleration forces



Purkinje cell morphology

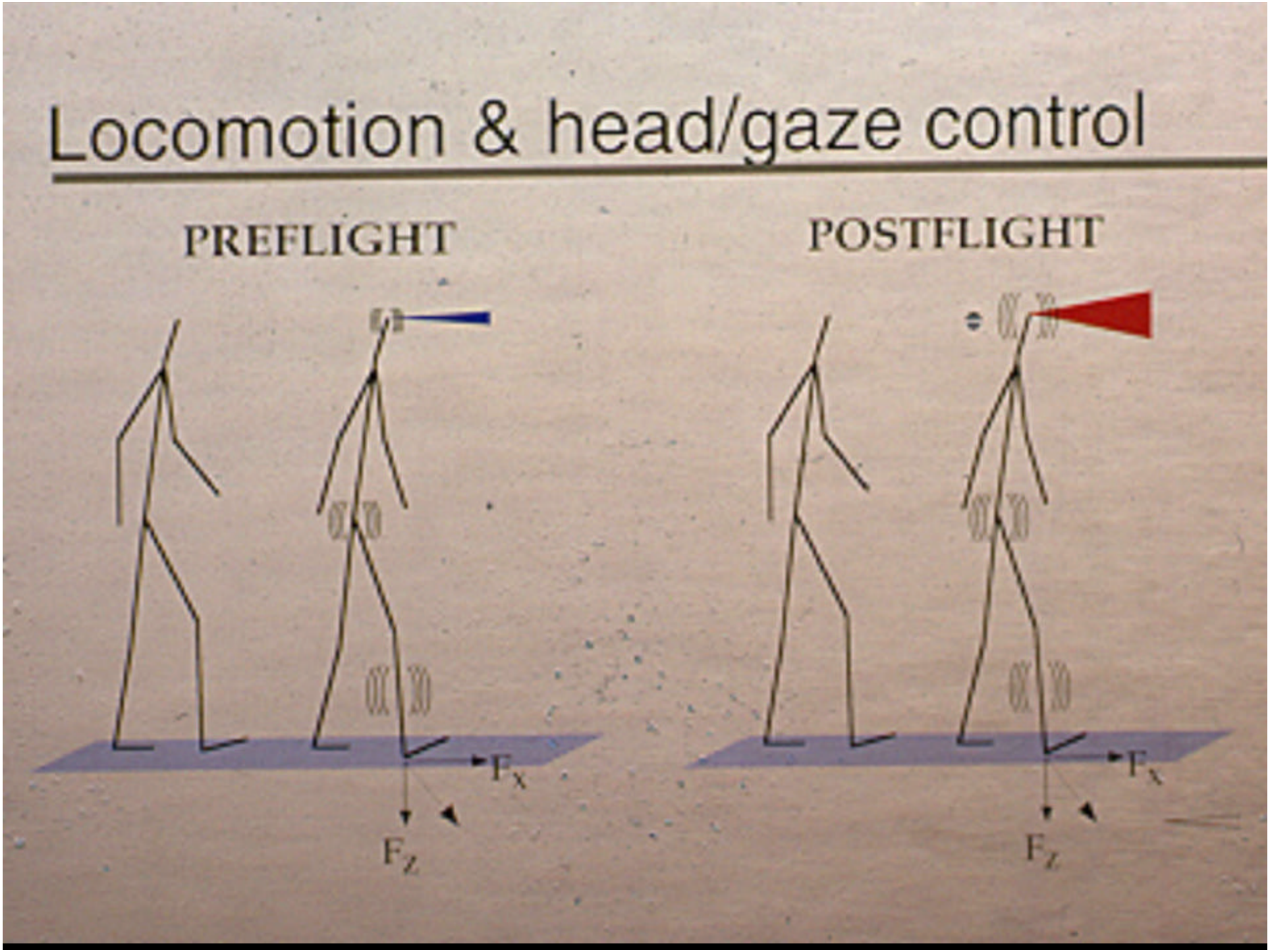
Type of Response



Synapses

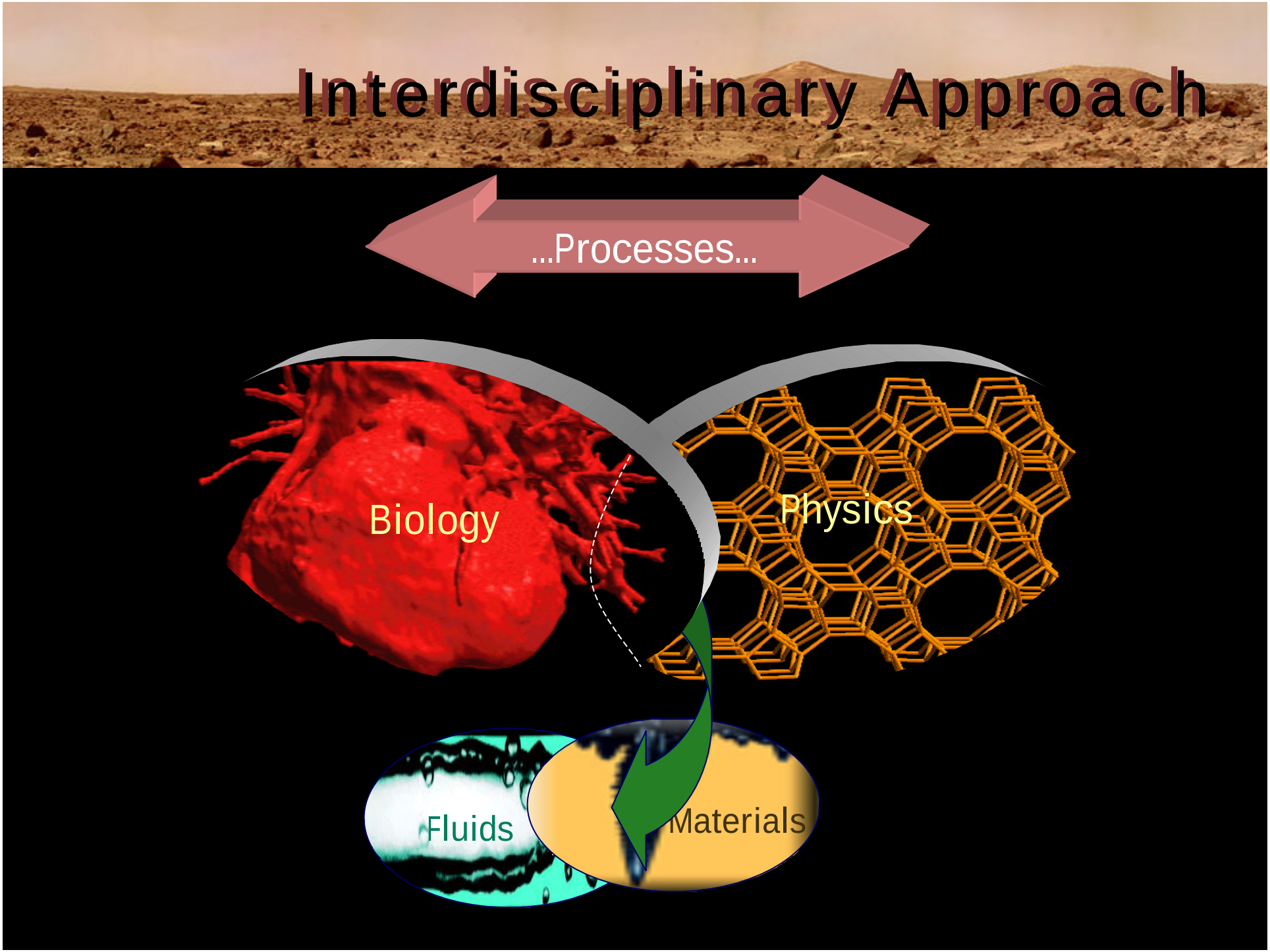
Ataxia
SMS
Occular

Locomotion & head/gaze control

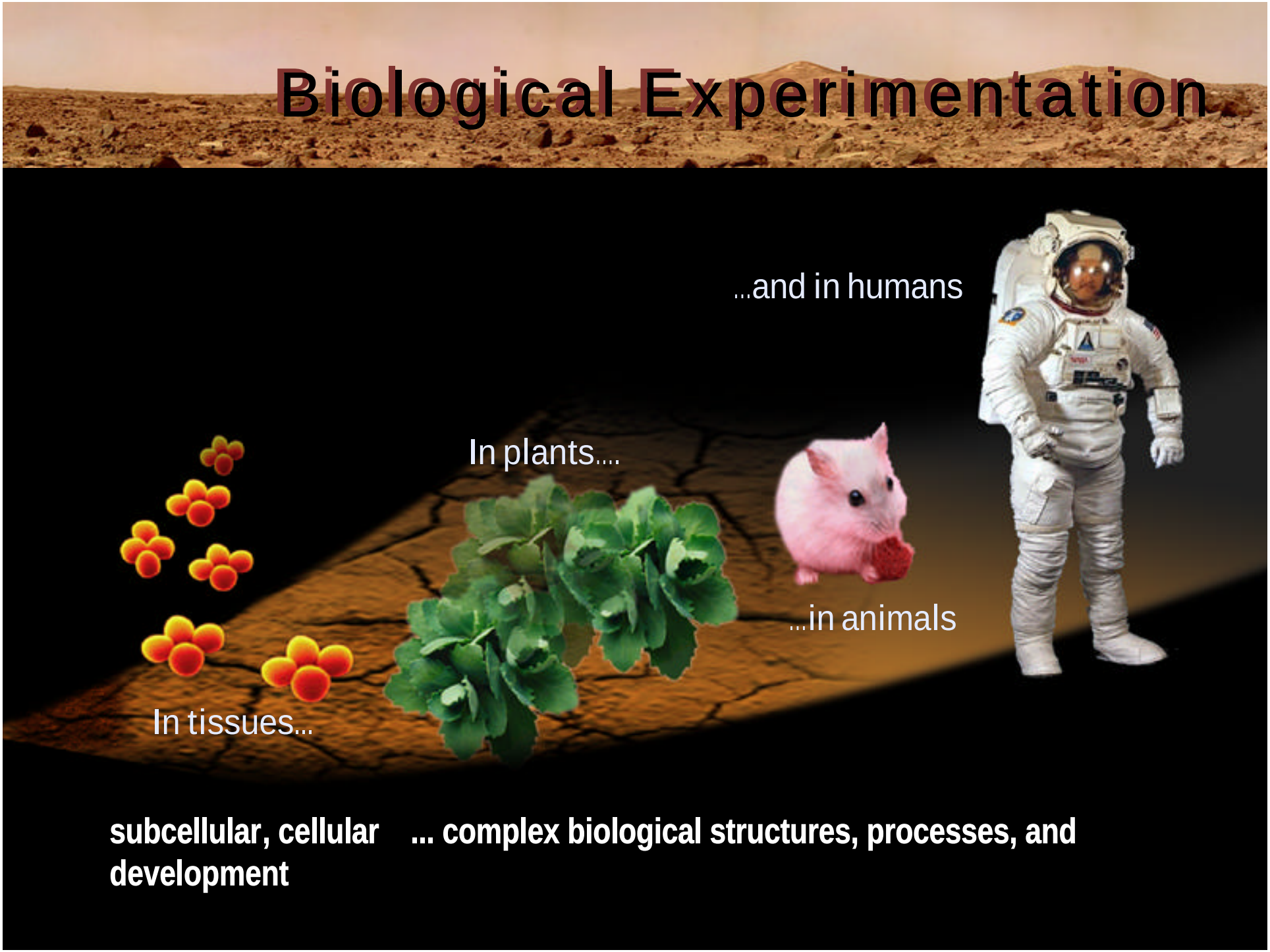



TED
TES

Interdisciplinary Approach

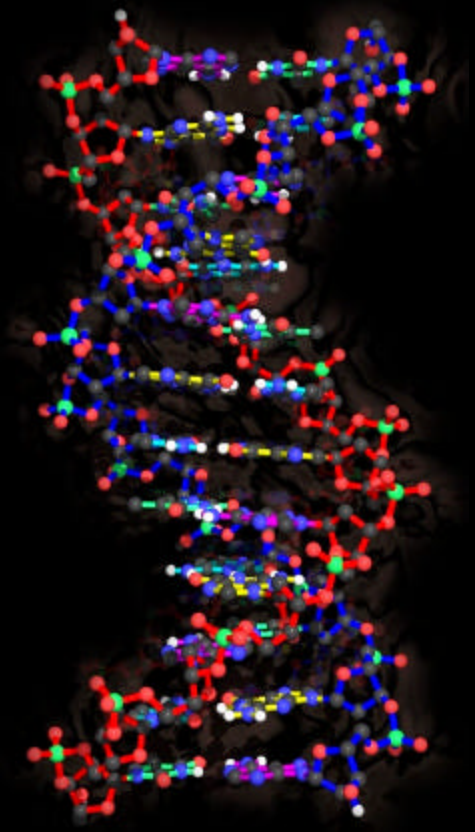


Biological Experimentation

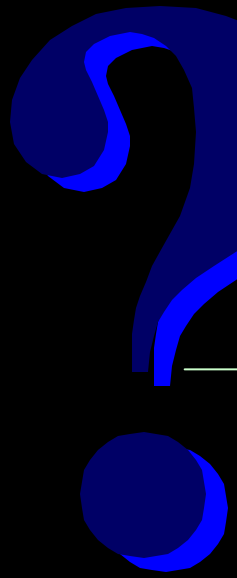


subcellular, cellular ... complex biological structures, processes, and development

Molecular Observations



Gene expression



Ca^{2+}

Calmoduline

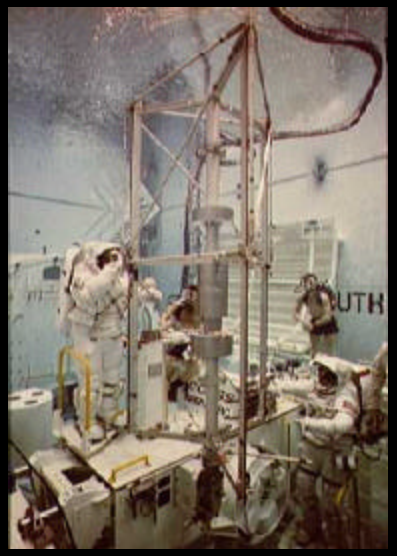
Apoptosis

Cell life-cycle

Training

Human System Environment

- **Survival**
- **Mission-specific**
- **Experiments**
- **Medical skills**



Protection

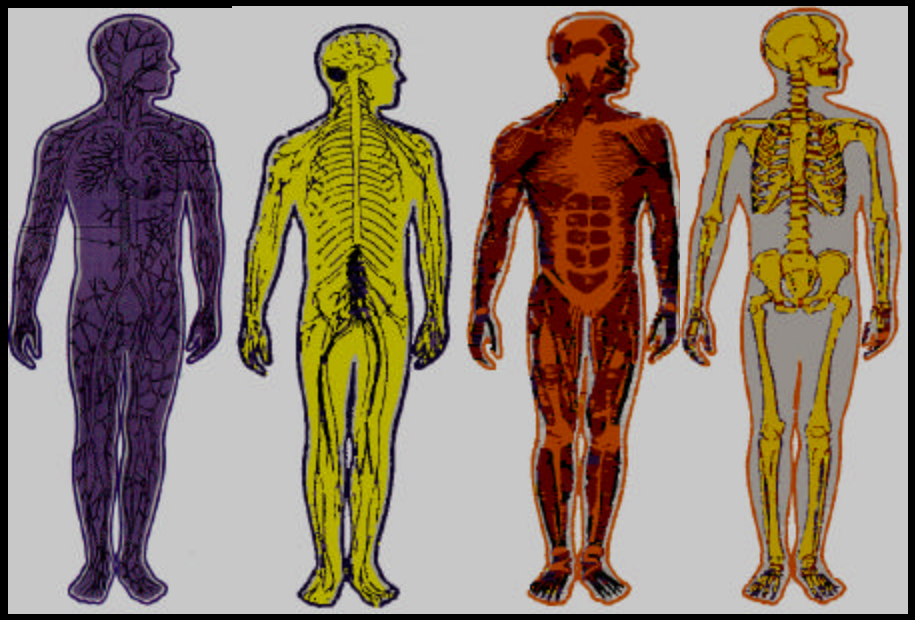
Human System Environment

- **Preventive care**
- **Interventions**
  - Countermeasures
  - Medical care
- **Life support design choices (system)**

Countermeasures

Mechanism

Plasticity	Receptor adjustment	Long chain myosin	Bone formation



Ataxia	Fluid loss (2 L), BP control	Muscle fiber shift & strength decrease	Reduction 1%/ month

Manifestation

- **Traditional**
  - Exercise
  - Nutrition
  - Fluids
  - Pharmacological supplements
- **Non-traditional**
  - Artificial gravity
  - Intervention at genetic/molecular level

Medical Events

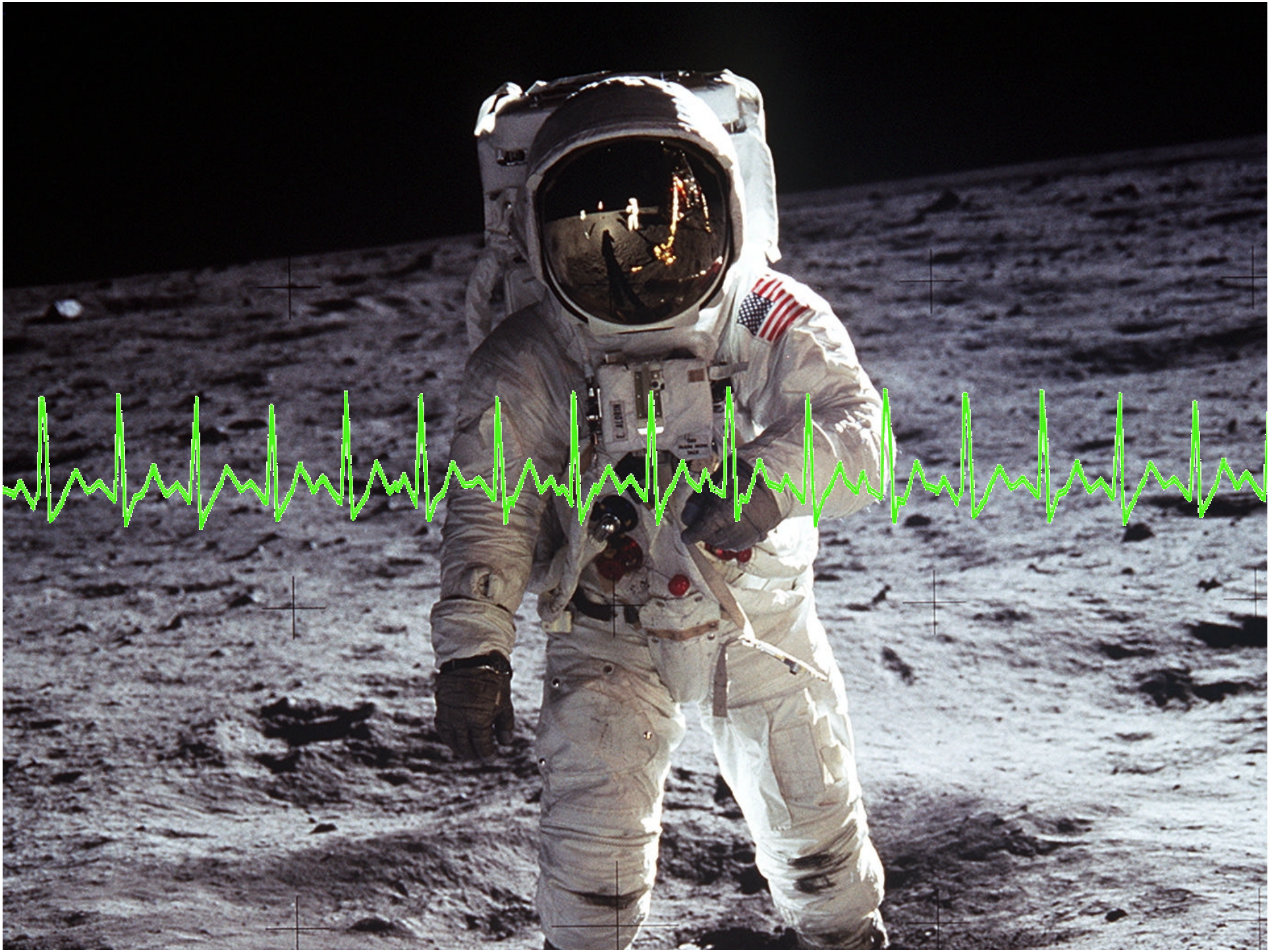
Cardio-vascular adaptations

Neuro-vestibular alterations

Bone & muscle changes

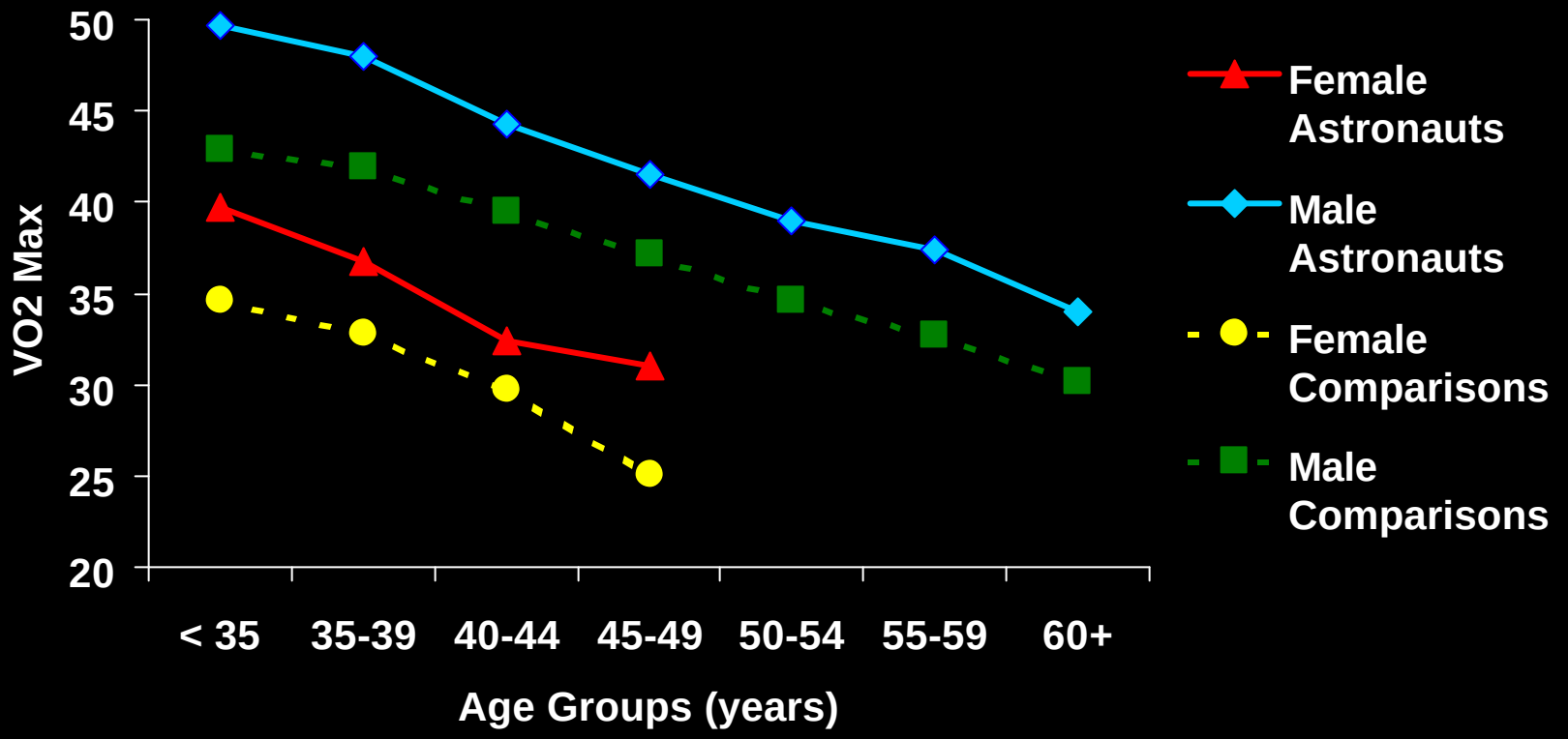
Metabolic/ hormonal shifts

Dry skin, Erythema of face & hands, Excessive wax in ear, Fatigue, Foreign body in eye, Gastrointestinal discomfort, Musculoskeletal changes, Nasal congestion/irritation, Psychiatric distress, Sleep disorders, Sleeplessness, Space motion sickness, Superficial injury, Surface burn to hands, Glossitis, Headache, Heartburn/ gas, Hematoma, Hemorrhoids, Injury/trauma, Laryngitis, Infection/irritation, Acute respiratory infection, Arrhythmia, Bruise, Conjunctivitis, Contact dermatitis, Contusion of eyeball, Dental caries



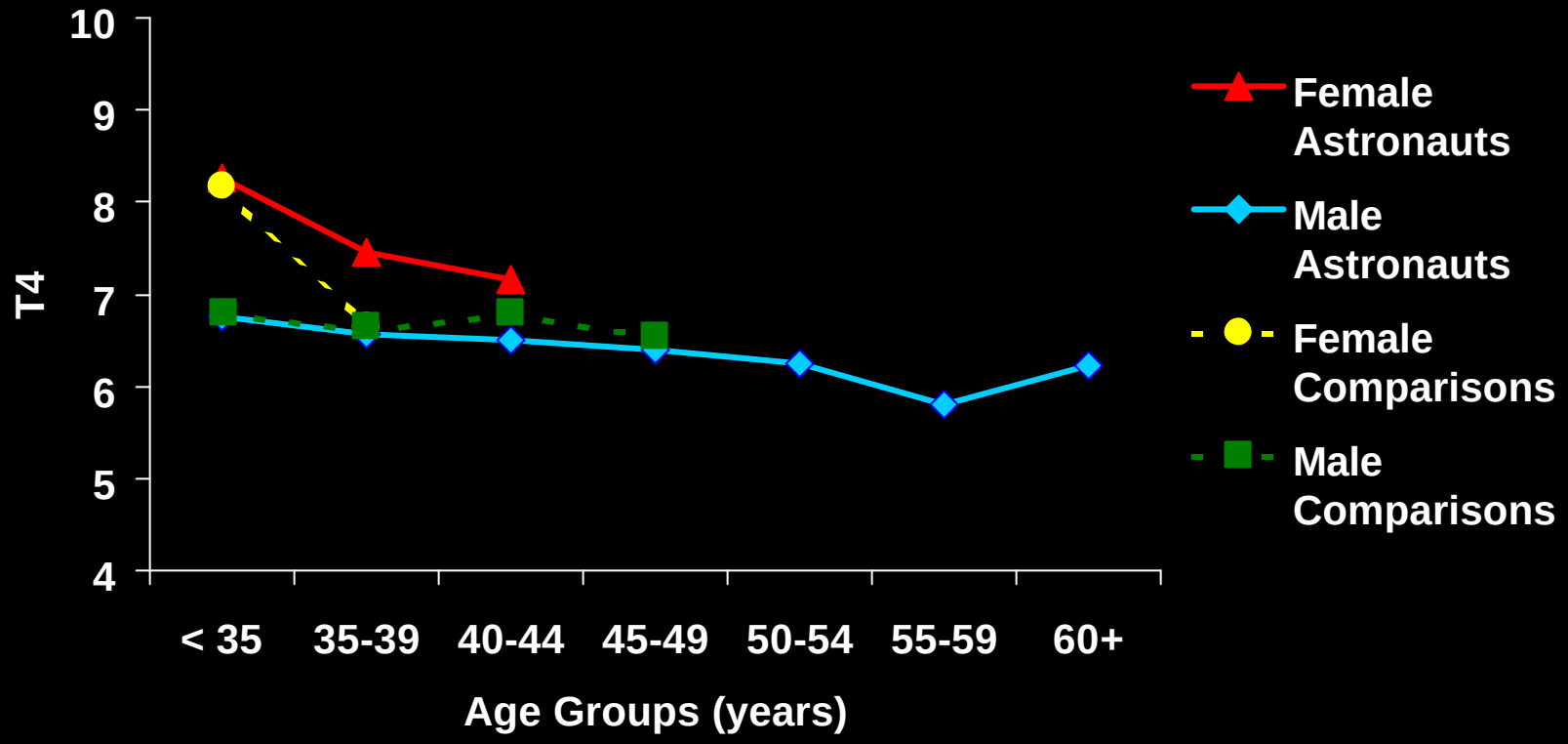
VO2 Max

Mean Values by Age (Cross-Sectional Data)



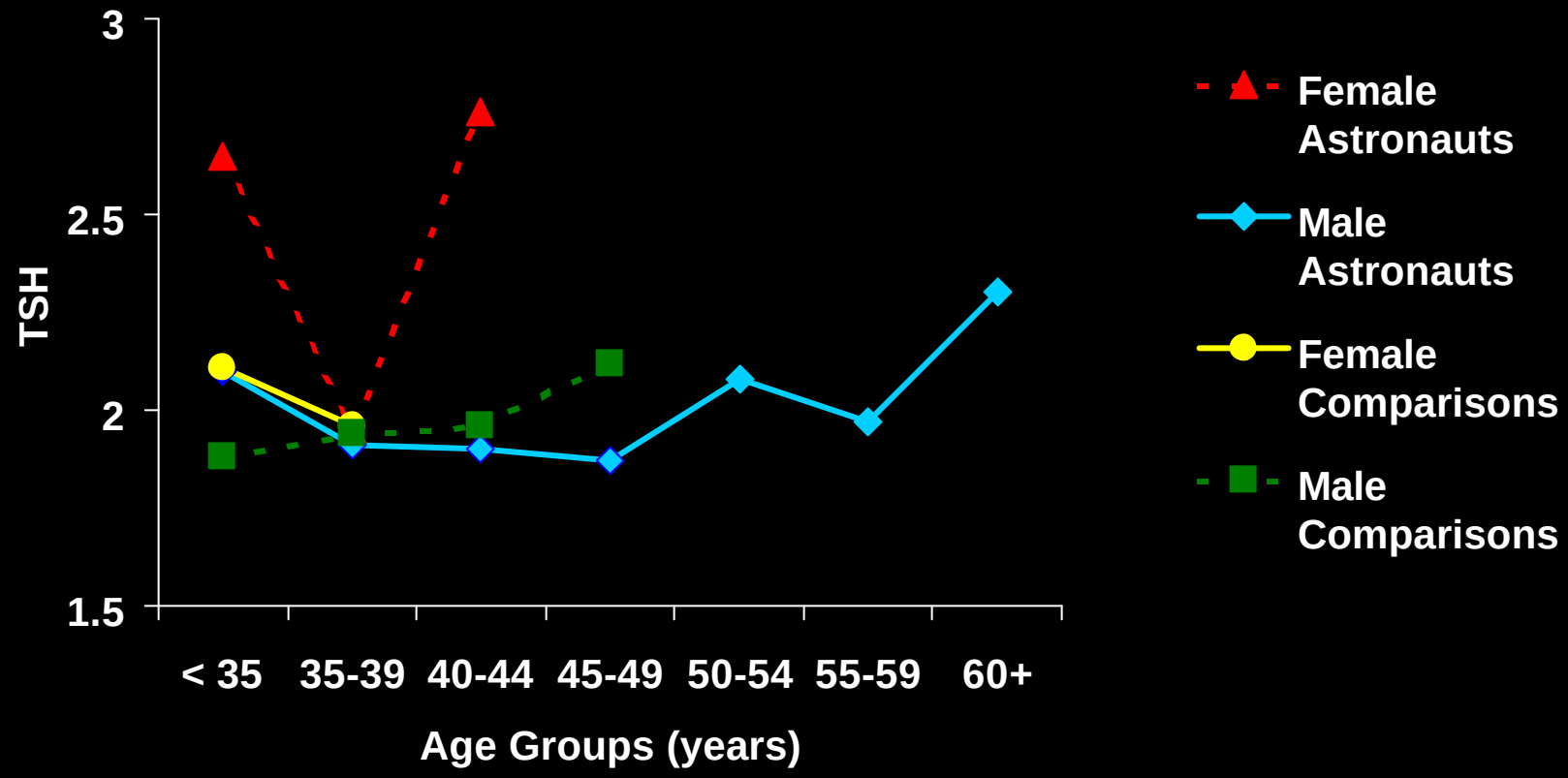
Thyroxine (T4)

Mean Values by Age
(Cross-sectional data, 1991-1998)



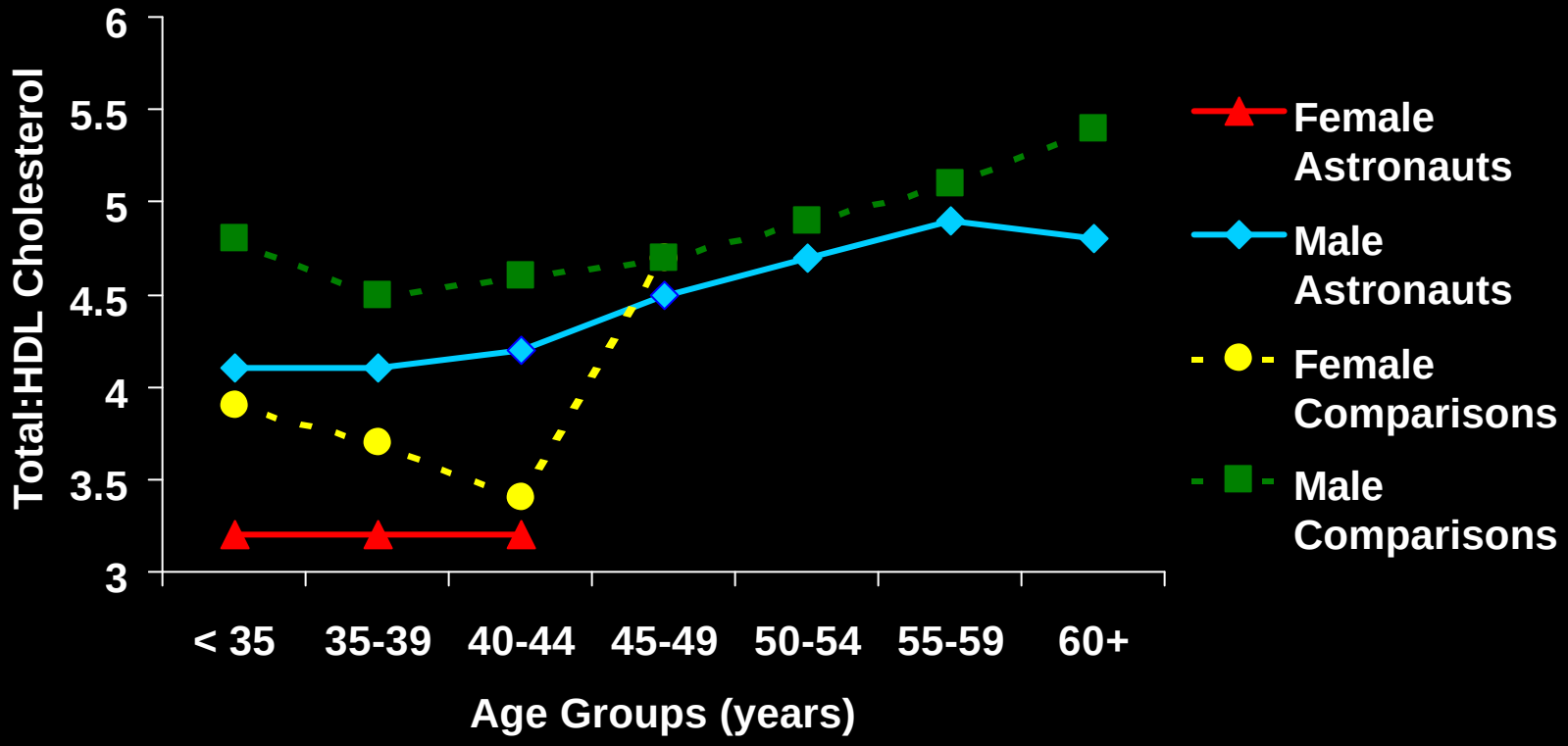
Thyroid Stimulating Hormone (TSH)

Mean Values by Age
(Cross-sectional data, 1991-1998)



Ratio of Total to HDL Cholesterol

Mean Values by Age (Cross-Sectional Data)



LSAH-Population

	Total	Living	Deceased
Astronauts	295		
Males	255	229	26
Females	40	39	1
Comparisons	909		
Males	778	764	14
Females	131	131	0

Current Age Distribution

Age Group	Astronauts Men	Astronauts Women	Comparisons Men	Comparisons Women
< 35	32	4	54	12
35-39	32	12	115	39
40-44	51	11	141	37
45-49	40	8	88	18
50-54	25	4	59	25
55-59	21	1	108	0
60-64	18	0	138	0
65+	27	0	52	0

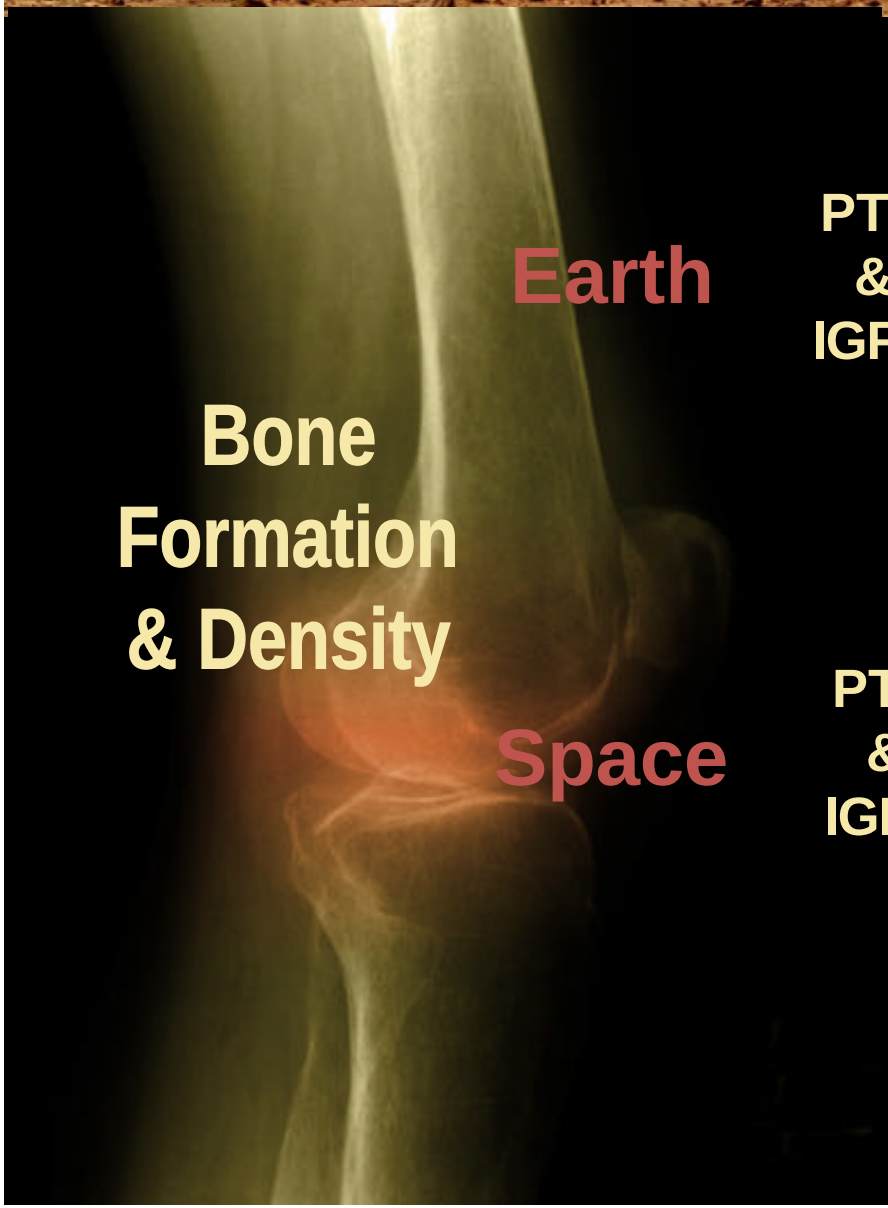
Mortality

	Astronauts	Comparisons
Total	27	14
Spacecraft Accidents	8	0
Other Accidents	11	2
Cancer	4	3
CVD/CHD	3	6
Other Conditions	1	3

Astronaut and Comparison Group Physical Examination Parameters

- Thyroid Stimulating Hormone(TSH)
- Tri-iodothyronine (T3)
- Thyroxine (T4)
- Sitting Blood Pressure / Pulse Pressure
- Body Mass Index (BMI) / Total Body Fat
- VO2 Max
- Hemoglobin
- Triglyceride
- Cholesterol/ HDL Cholesterol
- Intraocular Pressure
- Hearing, Right Ear at 1000 Hertz and 6000 Hertz

Bone Response



Bone Formation & Density

Earth

PTH & IGF-I ↑ = **Osteoprogenitor Number & Bone Mineralization**

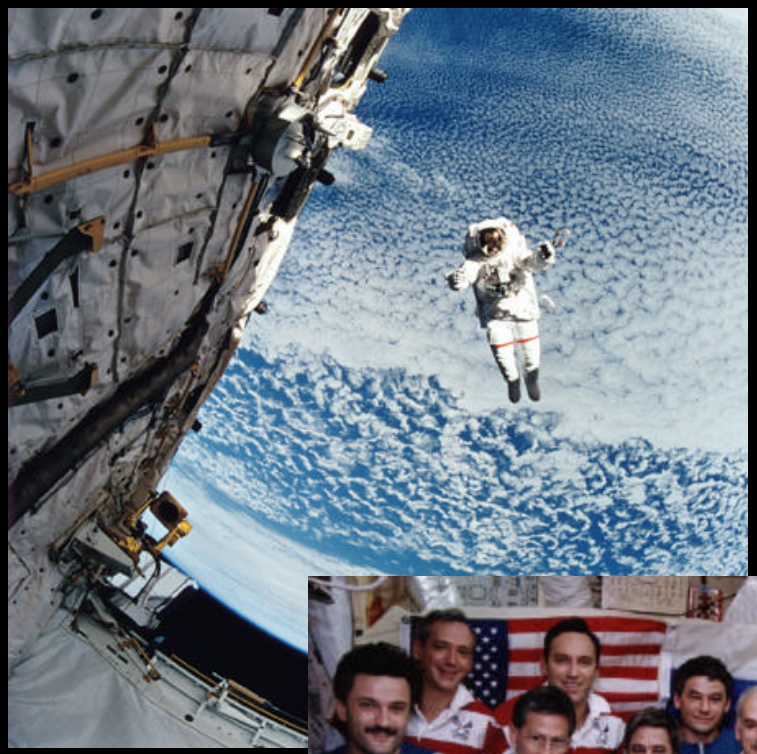
Space

PTH & IGF-I ↓ = **Osteoprogenitor Number & Bone Mineralization**

Internal

Psychosocial Elements

System Human Environment



- Isolation
- Confinement
- Multicultural factors
- Societal issues

Physical Examinations

Human System Environment

- **Types of examinations**
  - Selection
  - Retention
  - Pre-flight
  - Post-flight
  - Post-retirement
- **Components of examinations**
  - Physical exam
  - Laboratory analysis
  - Imaging
  - Special studies

Longitudinal Study of Astronaut Health